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F16L 1/26

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F2P PL2 P37
F2G G8
U1S S2316

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GB 2316992 A GB 2300439 A WO 97/47856 A1

(58) Field of Search
UK CL (Edition P) F2G G8, F2P PL2 PL9
INT CL[6] F16L 1/26 55/18

(54) Abstract Title
Method and apparatus for connecting underwater conduits

(57) Underwater conduits (C) are connected by remotely operated devices including a vehicle 80 capable of underwater excursions (ROV), and apparatus for connecting conduits 10, by a method controlled e.g. from a support vessel on the surface, comprising launching the ROV and connection apparatus 10, manipulating the ROV 80 to dock with the connecting apparatus; installing the connection apparatus at one of the conduits c; activating a docking clamp means using the ROV to capture the end of the other conduit C'; activating the connection apparatus to draw the second conduit to the first; connecting the two conduits together to form a continuous flowline; providing a sealed connection and recovering the ROV and connection apparatus to the support vessel.

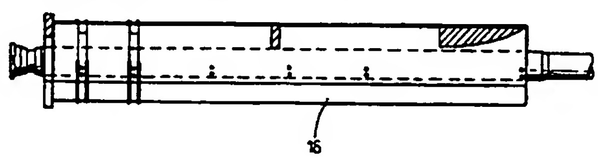


Fig. 3

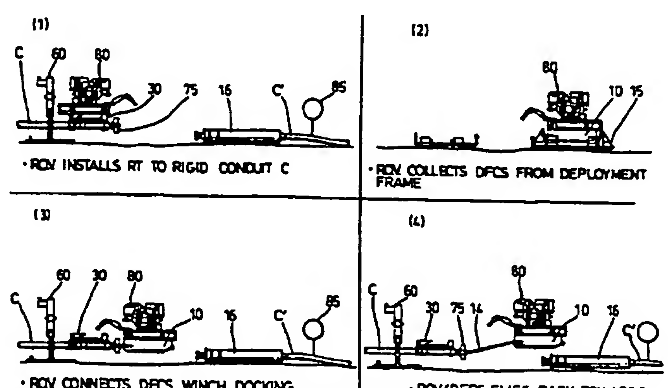


Fig. 13

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

GB 2 323 907 A

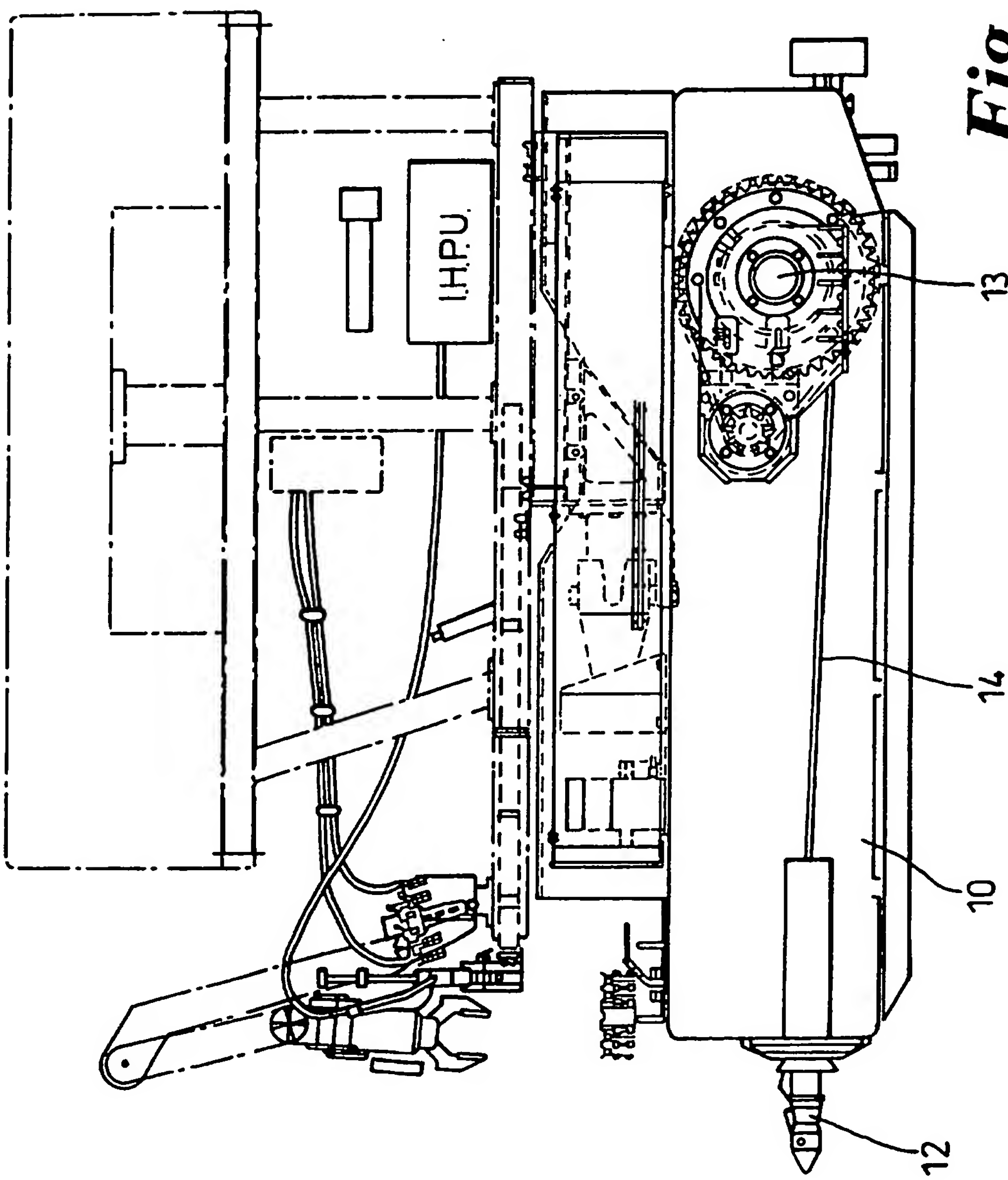


Fig. 1

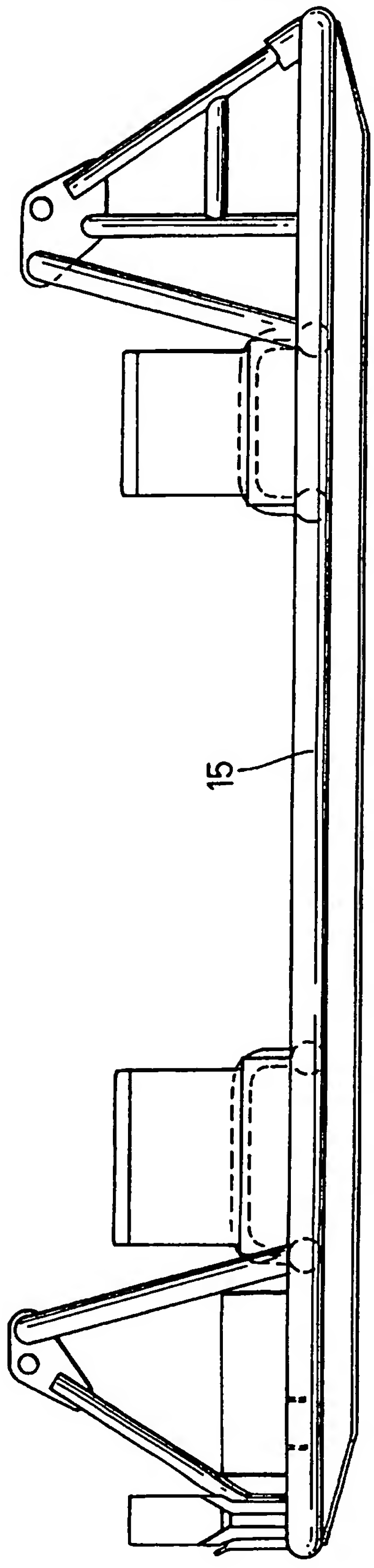


Fig. 2

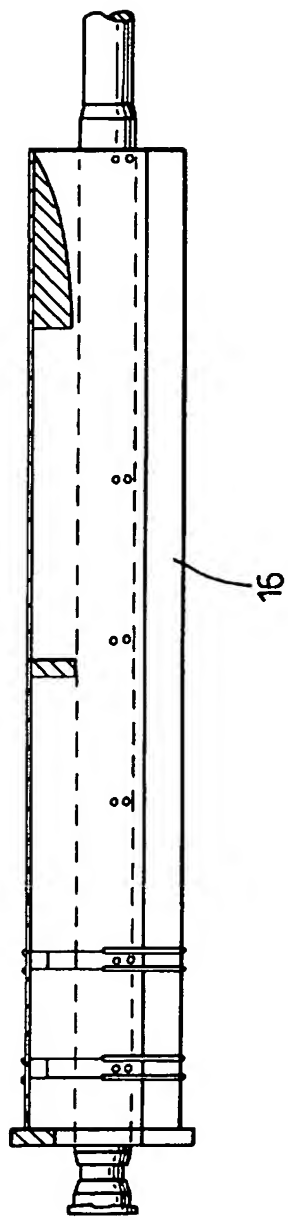


Fig. 3

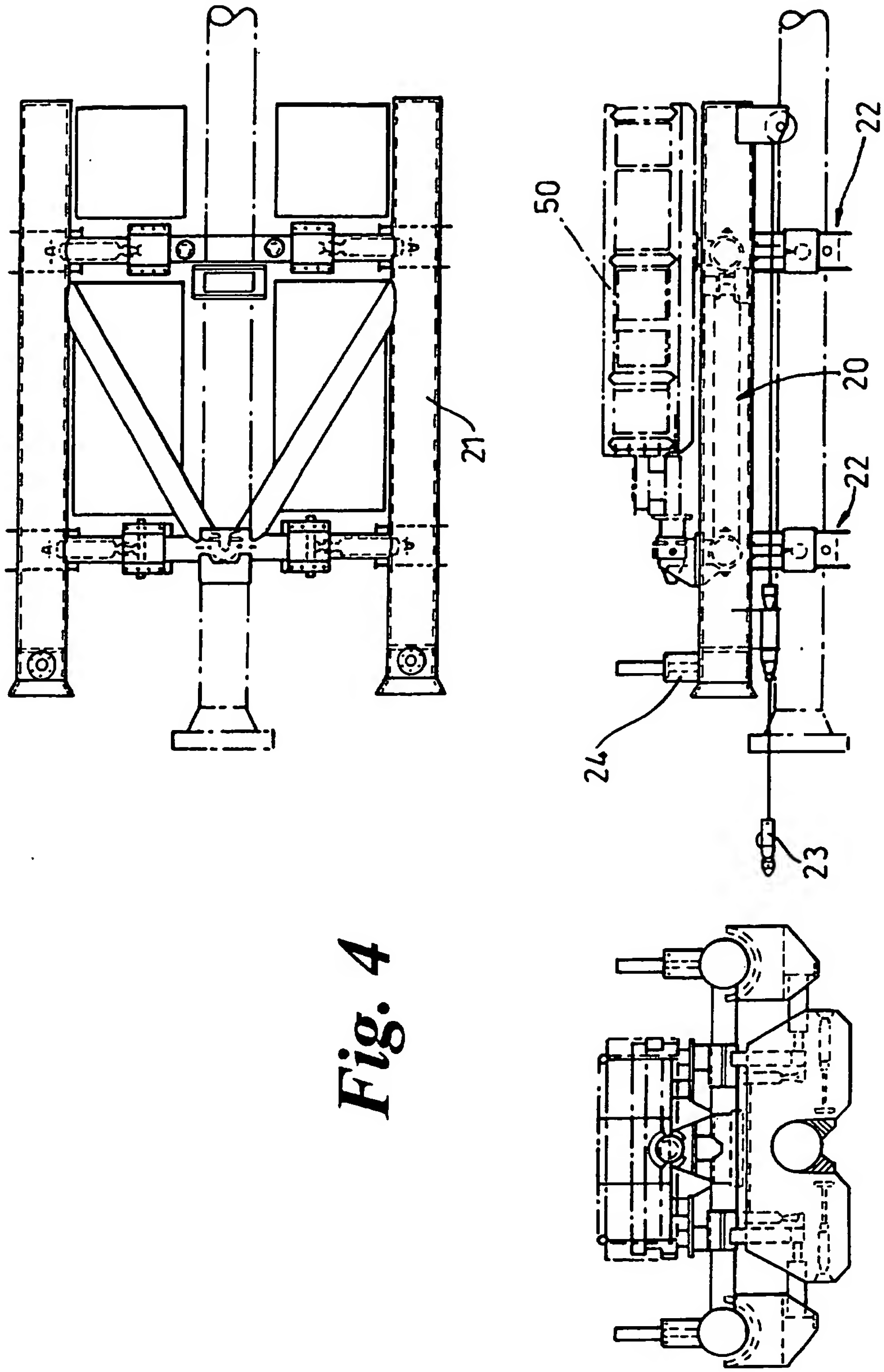


Fig. 4

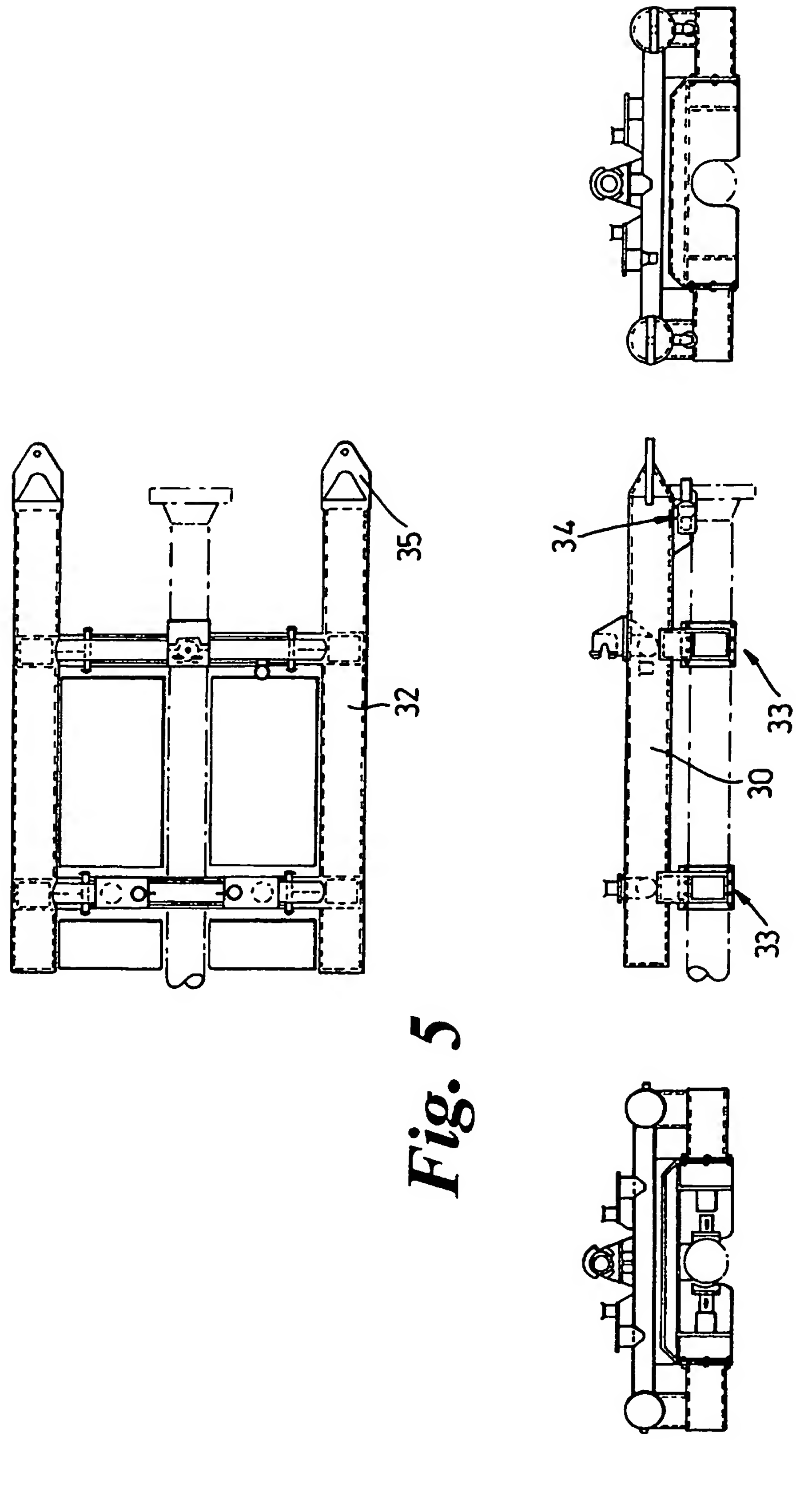


Fig. 5

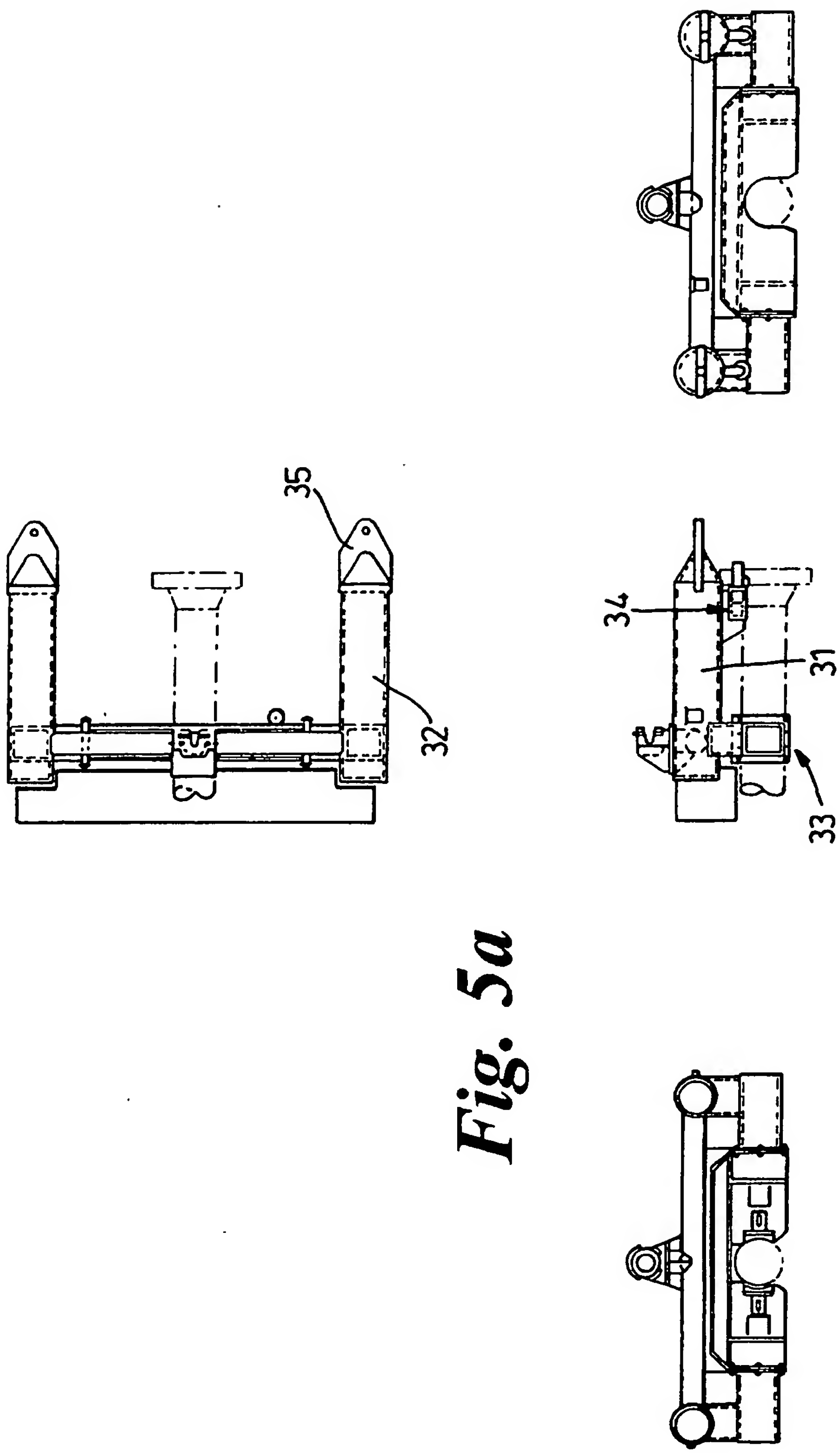


Fig. 5a

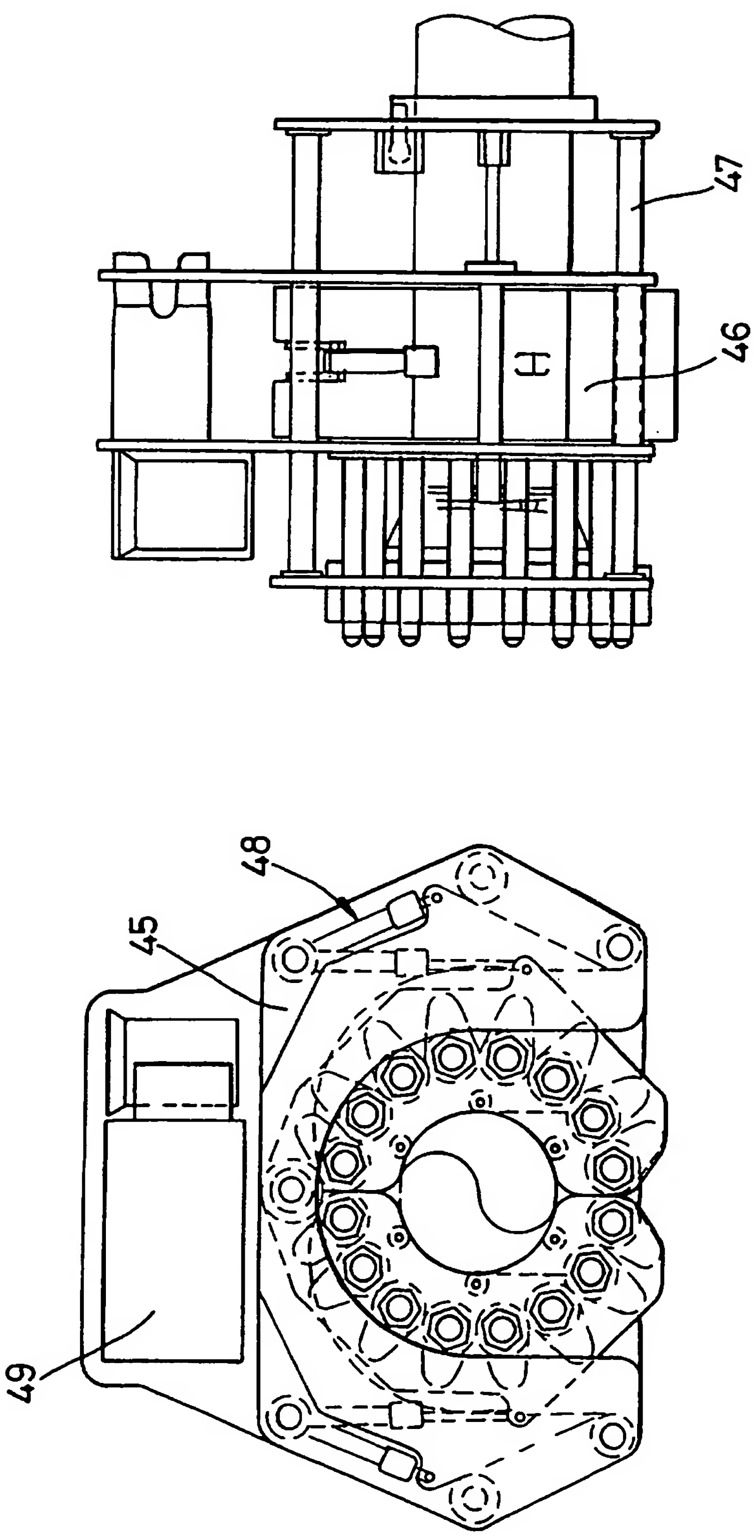


Fig. 6(part 1)

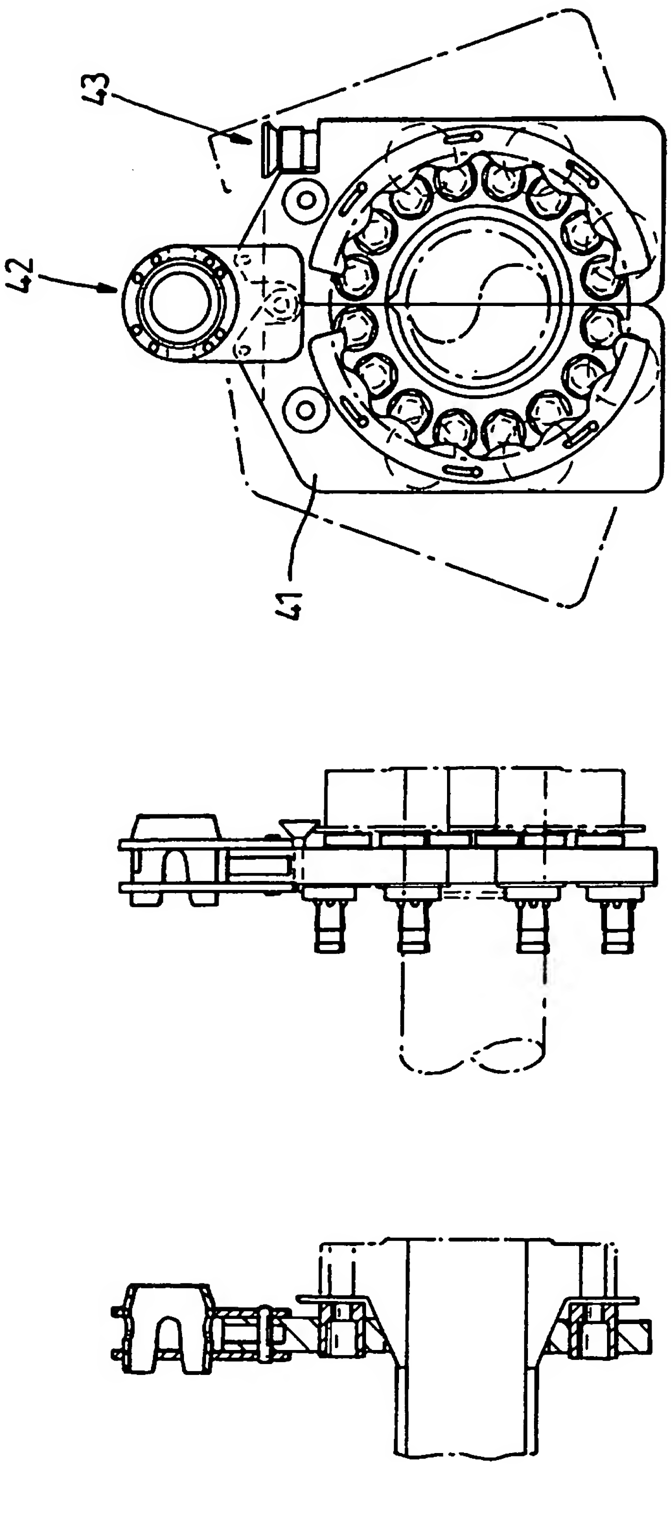


Fig. 6(part 2)

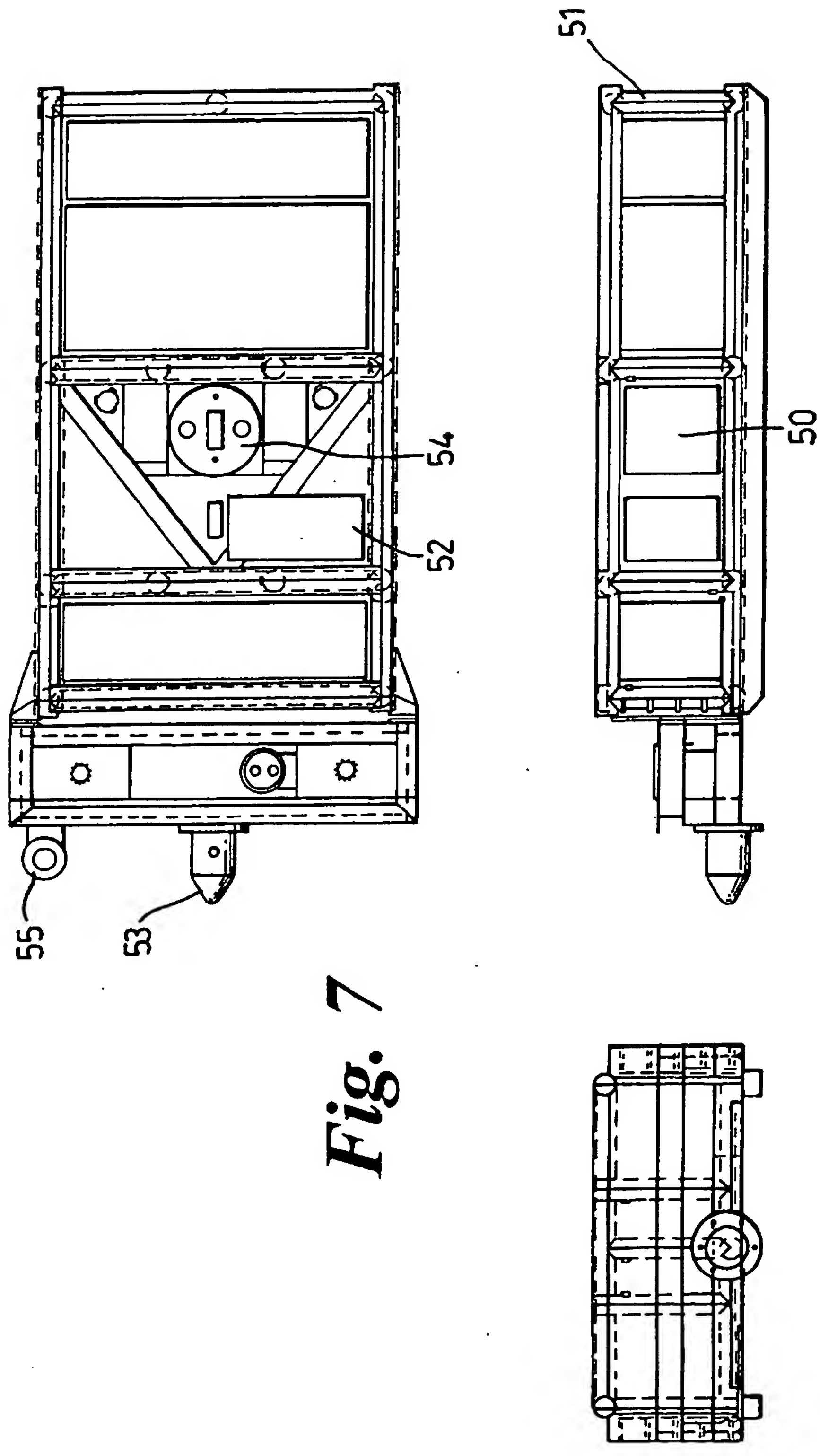


Fig. 7

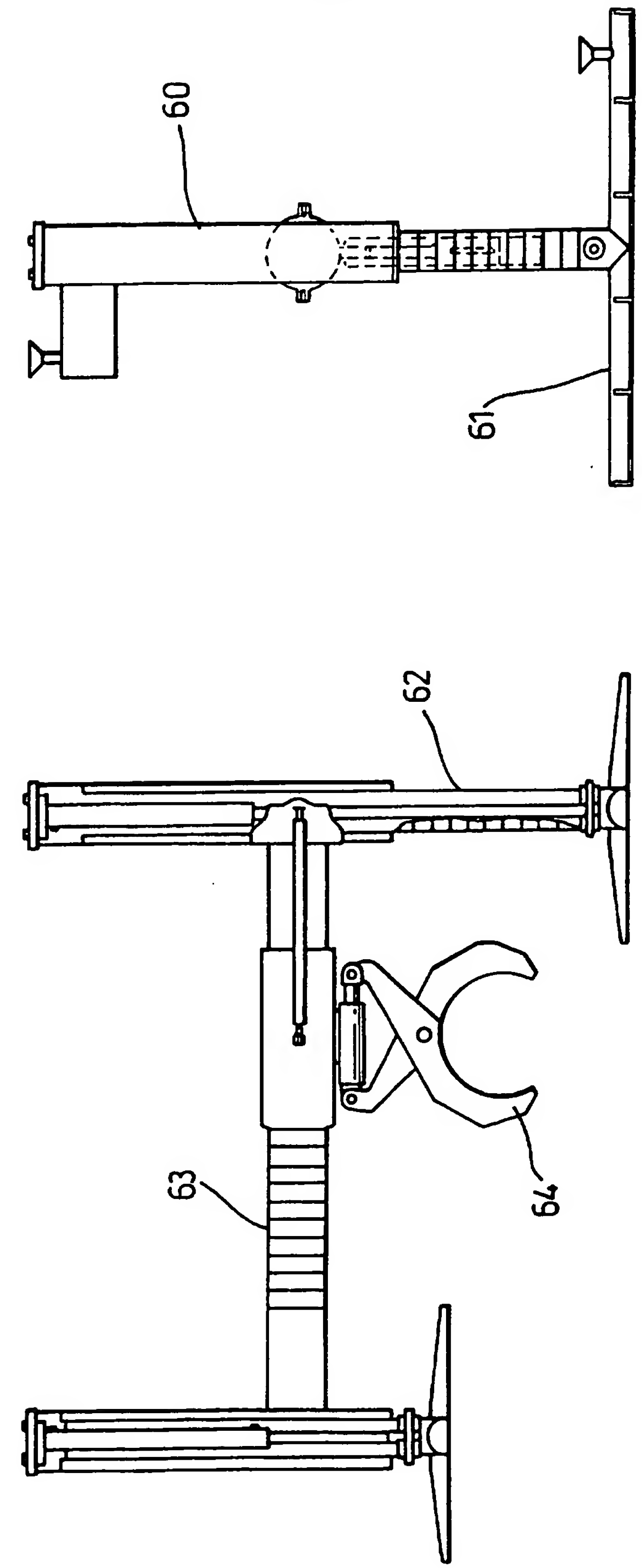


Fig. 8

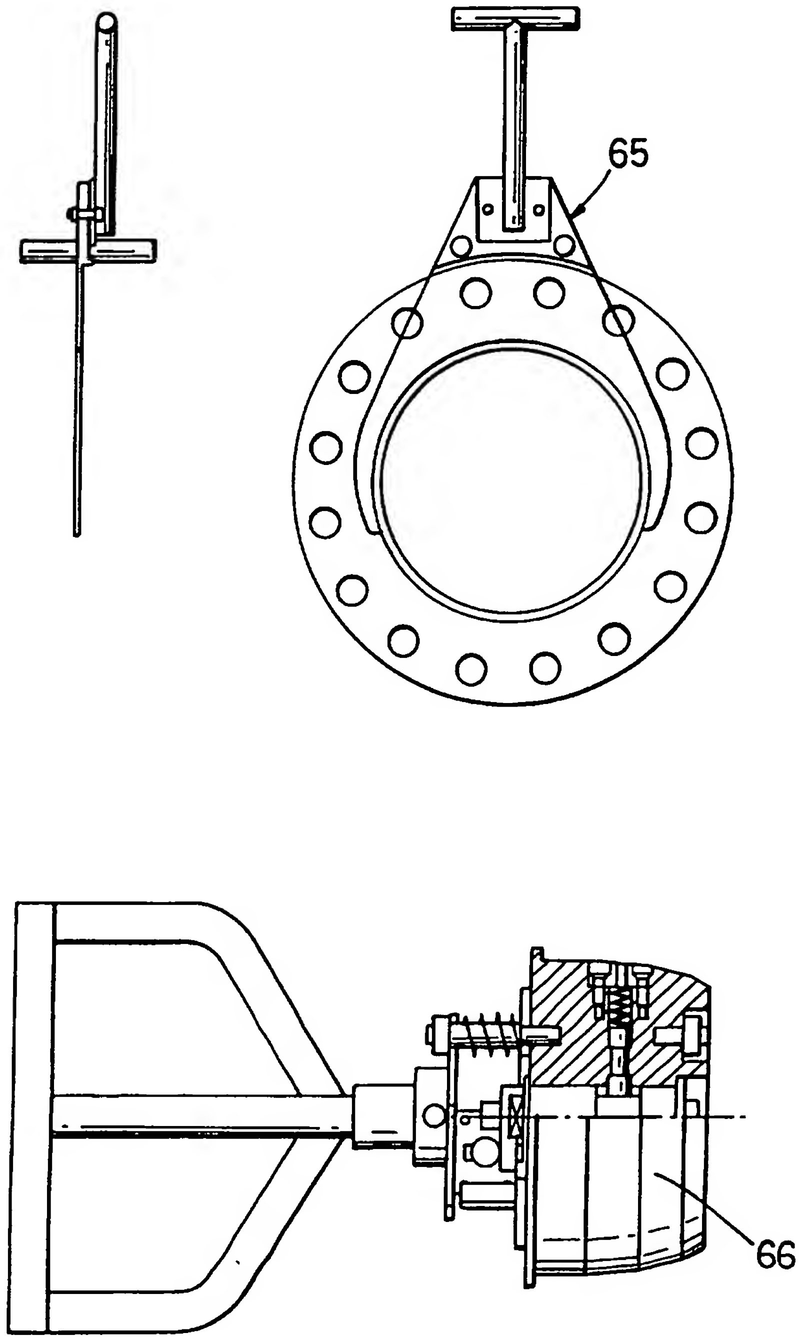


Fig. 9

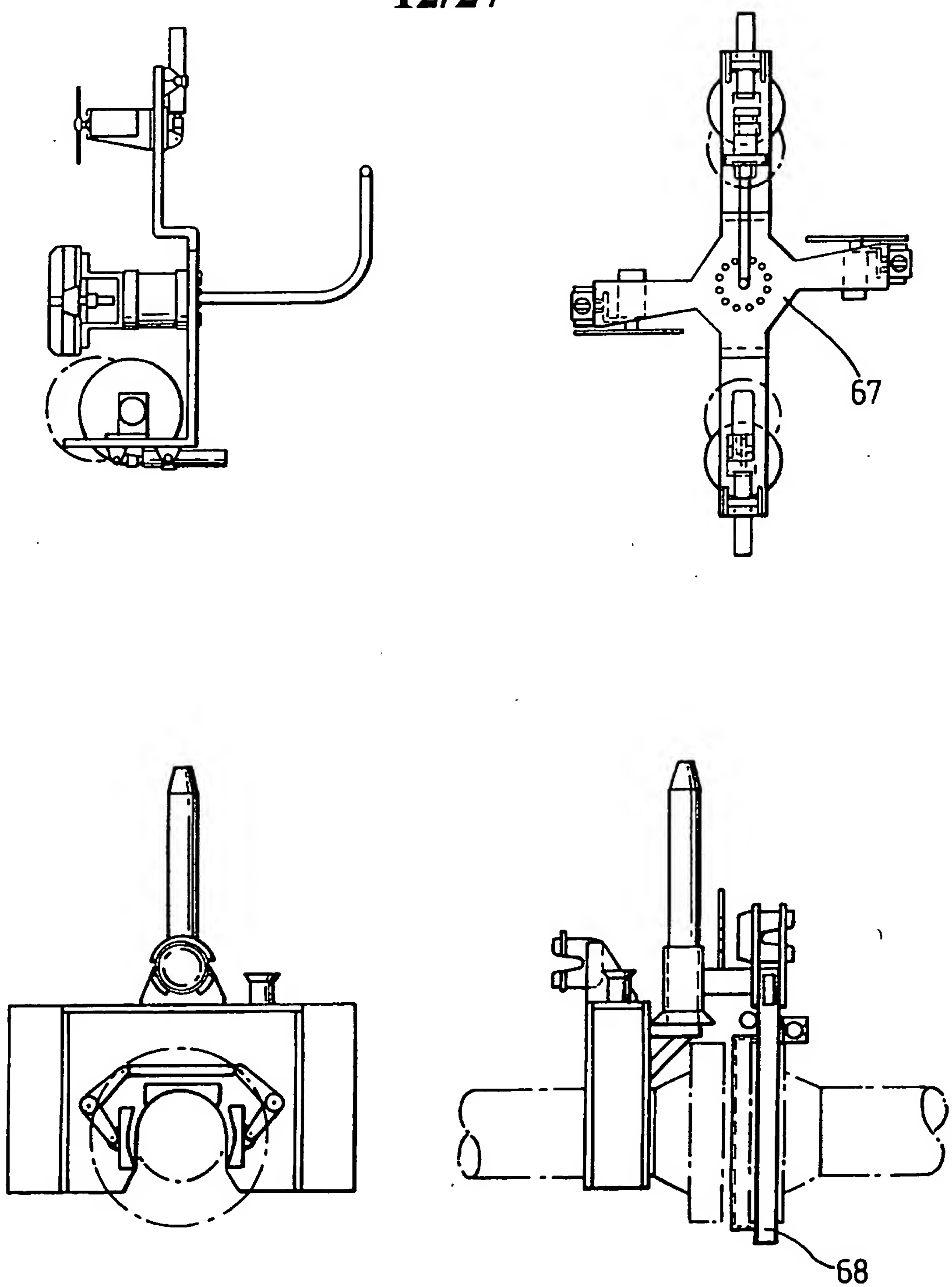


Fig. 10

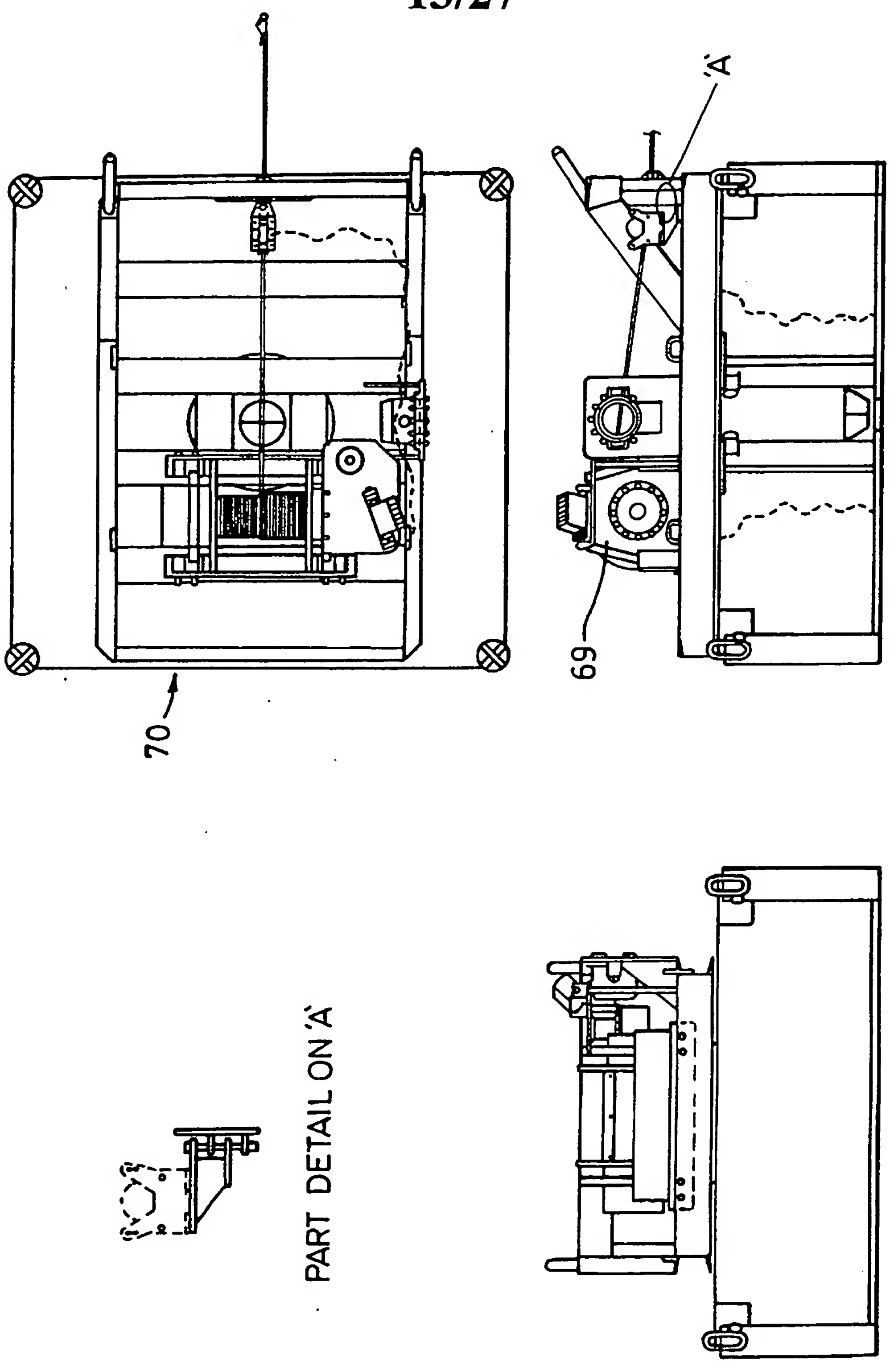


Fig. 11

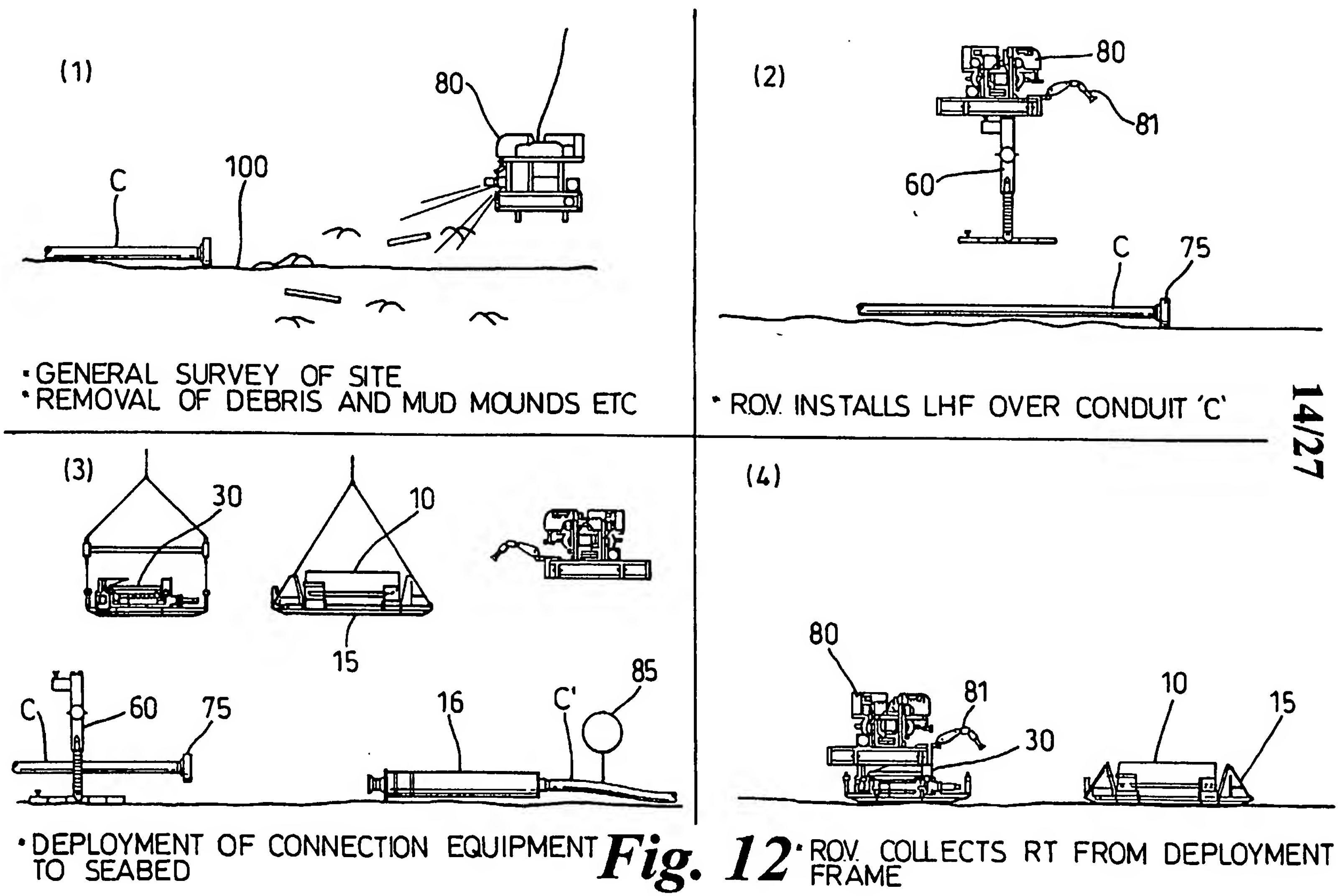

(1)
C
100
80
• GENERAL SURVEY OF SITE
• REMOVAL OF DEBRIS AND MUD MOUNDS ETC
(2)
80
81
60
C
75
• R.O.V. INSTALLS LHF OVER CONDUIT 'C'
(3)
30
10
15
C
60
75
16
C'
85
• DEPLOYMENT OF CONNECTION EQUIPMENT TO SEABED
(4)
80
81
30
10
15
• R.O.V. COLLECTS RT FROM DEPLOYMENT FRAME

Fig. 12

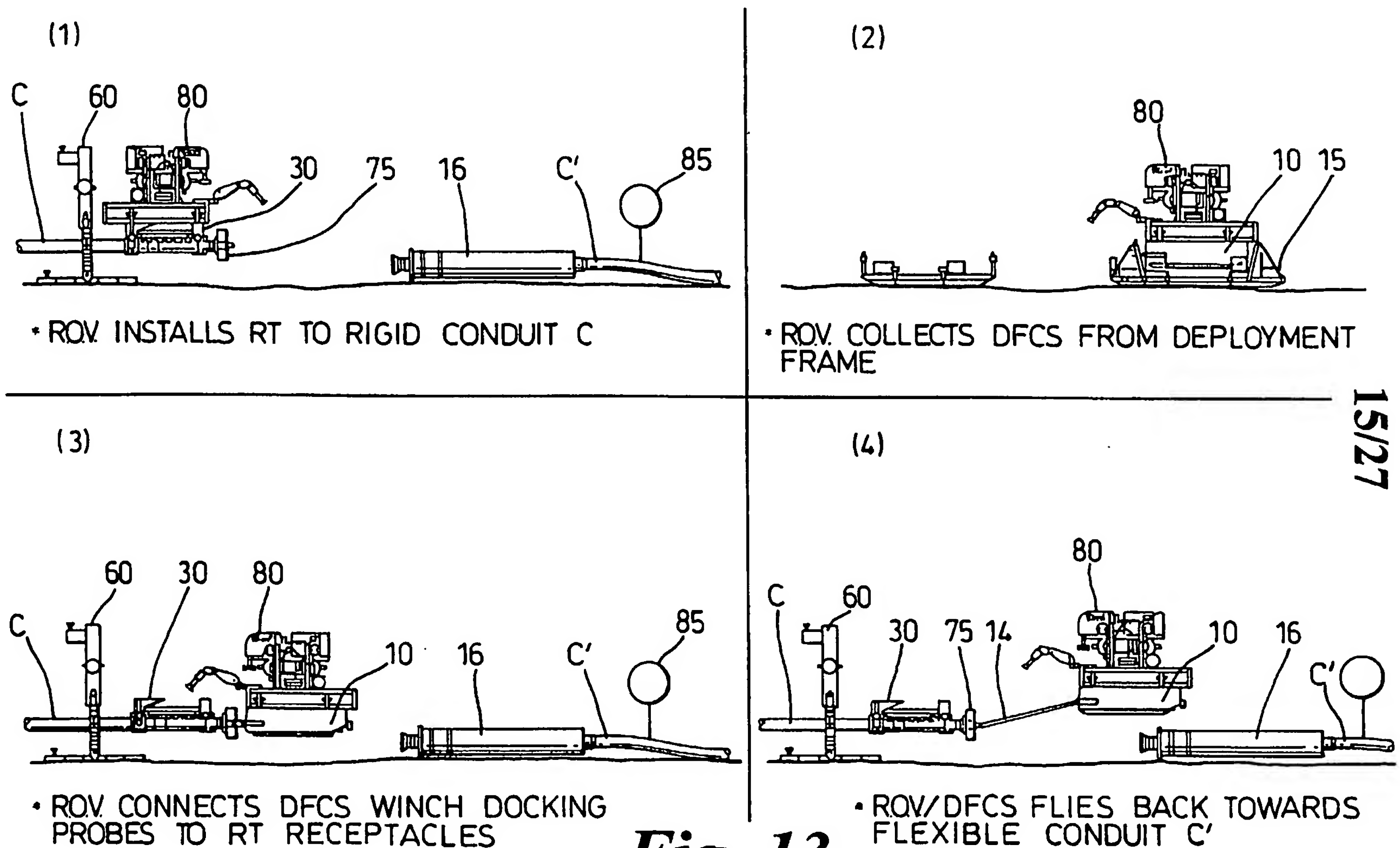

(1)
C
60
80
30
75
16
C'
85
• R.O.V. INSTALLS RT TO RIGID CONDUIT C
(2)
80
10
15
• R.O.V. COLLECTS DFCS FROM DEPLOYMENT FRAME
(3)
C
60
30
80
10
16
C'
85
• R.O.V. CONNECTS DFCS WINCH DOCKING PROBES TO RT RECEPTACLES
(4)
C
60
30
75
14
80
10
16
C'
• R.O.V./DFCS FLIES BACK TOWARDS FLEXIBLE CONDUIT C'

Fig. 13

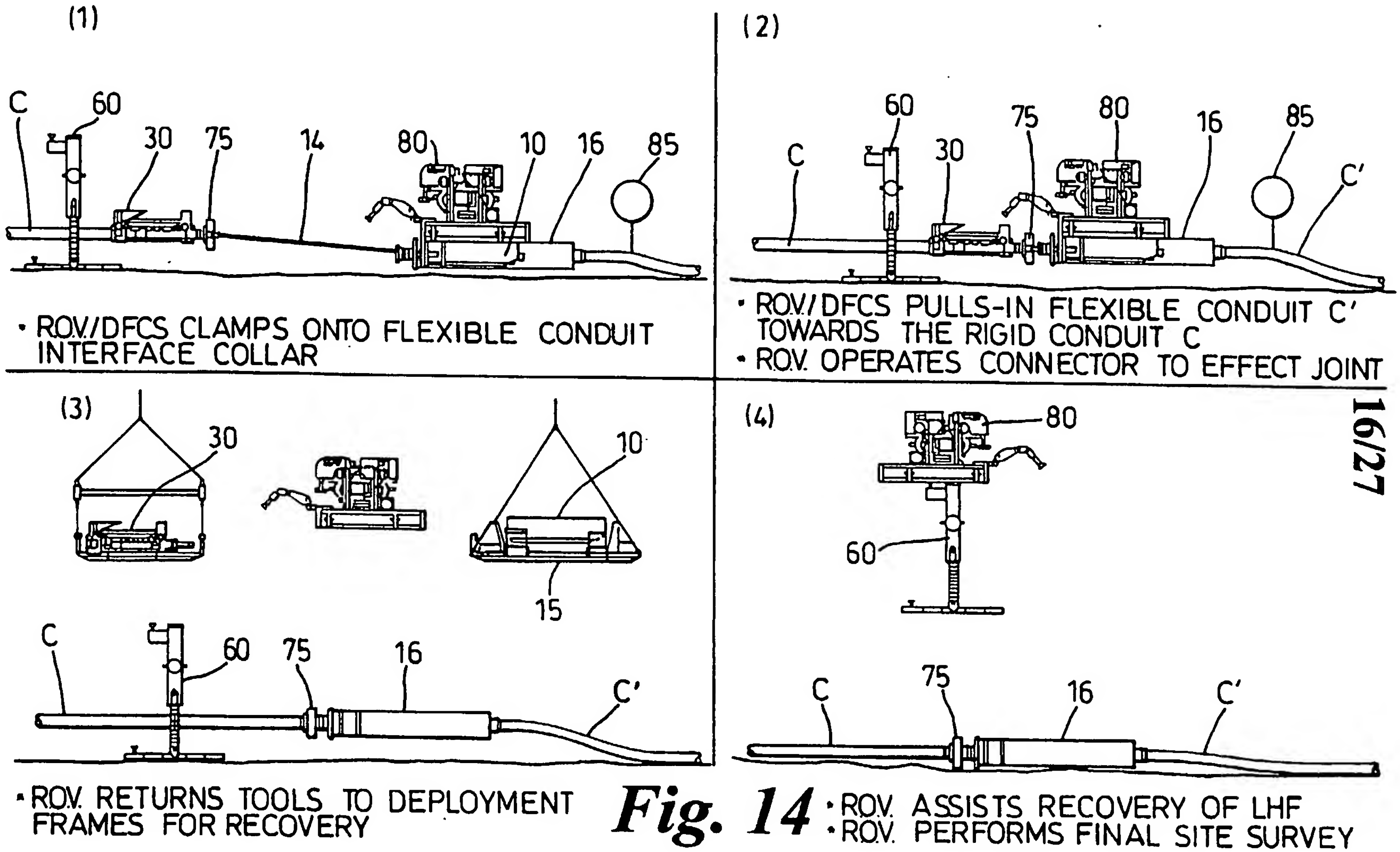
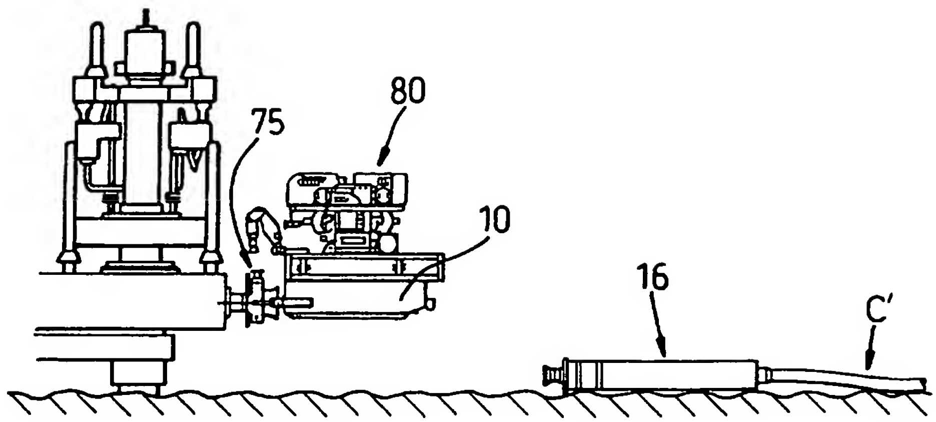

(1)
C
60
30
75
14
80
10
16
85
• ROV/DFCS CLAMPS ONTO FLEXIBLE CONDUIT INTERFACE COLLAR
(2)
C
60
30
75
80
16
85
C'
• ROV/DFCS PULLS-IN FLEXIBLE CONDUIT C' TOWARDS THE RIGID CONDUIT C
• ROV. OPERATES CONNECTOR TO EFFECT JOINT
(3)
30
10
15
C
60
75
16
C'
• ROV. RETURNS TOOLS TO DEPLOYMENT FRAMES FOR RECOVERY
(4)
80
60
C
75
16
C'
• ROV. ASSISTS RECOVERY OF LHF
• ROV. PERFORMS FINAL SITE SURVEY

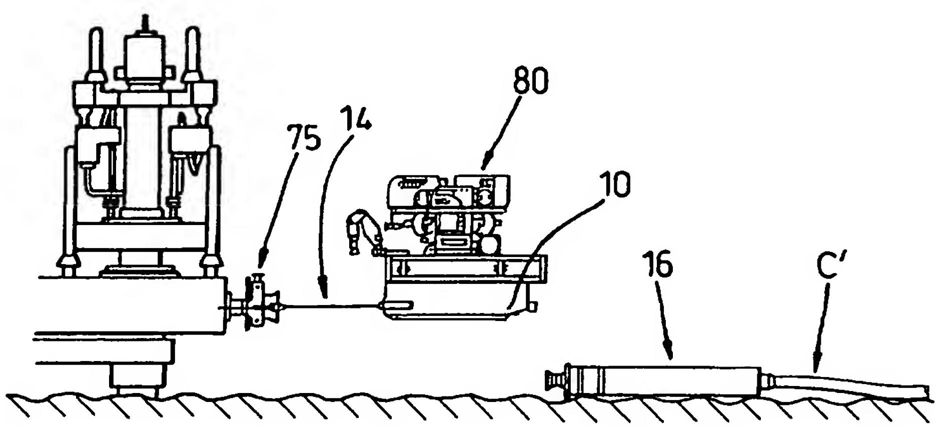
Fig. 14

(1)



• DFCS WINCH DOCKING PROBES LATCHING INTO RECEPTACLE AT XMAS TREE CONNECTOR

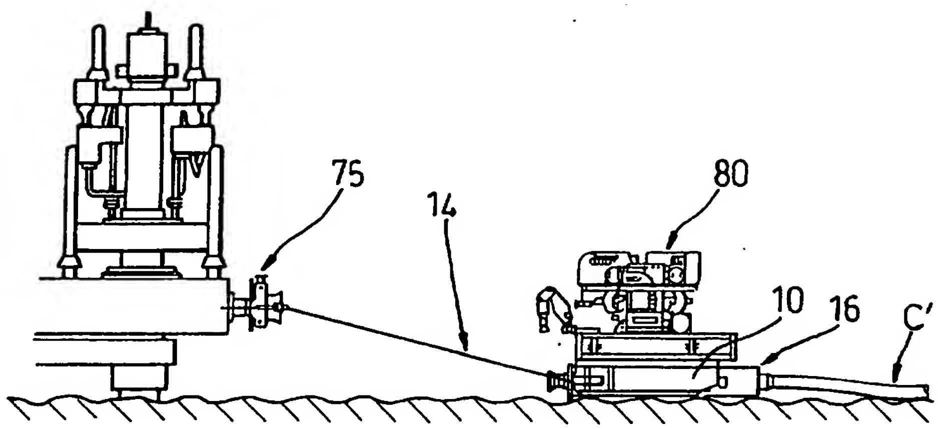
(2)



• DFCS PAYS OUT WINCHES & FLIES BACK TO FLEXIBLE CONDUIT

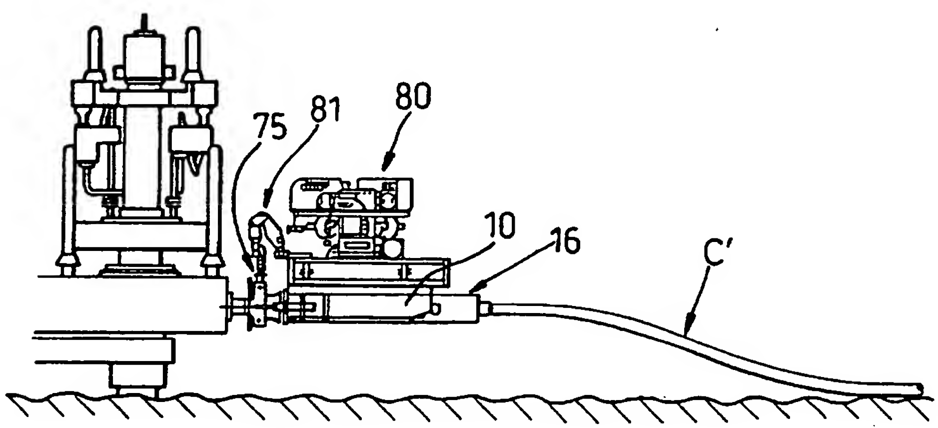
Fig. 15

(1)



* ROV/DFCS CLAMPING ONTO FLEXIBLE CONDUIT INTERFACE COLLAR

(2)



* ROV/DFCS PULLS-IN FLEXIBLE CONDUIT C' TOWARDS THE XMAS TREE CONNECTOR.
* ROV OPERATES CONNECTOR TO EFFECT JOINT

Fig. 16

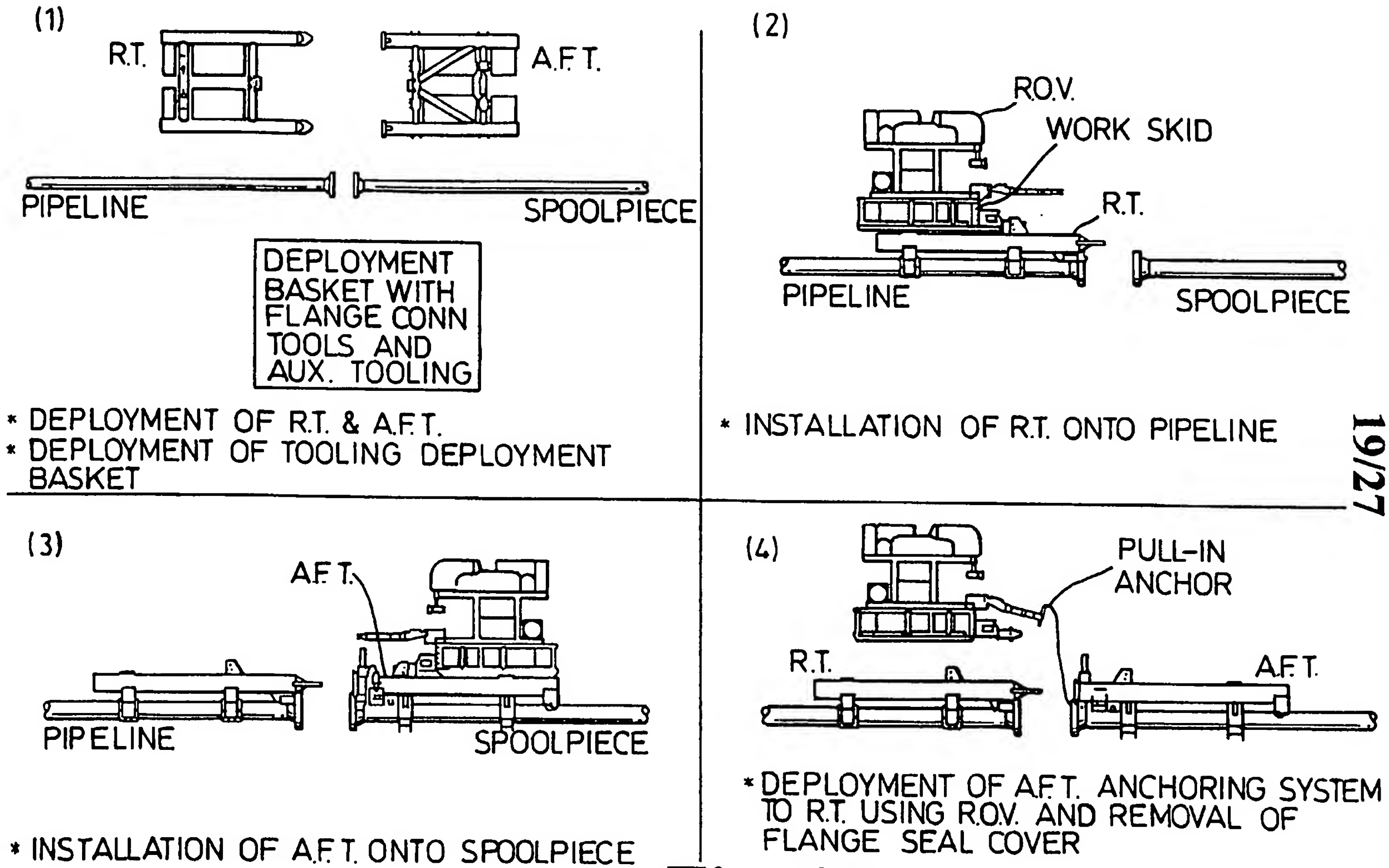
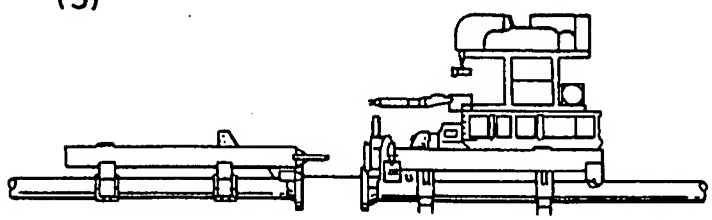

(1)
R.T.
A.F.T.
PIPELINE
SPOOLPIECE
DEPLOYMENT BASKET WITH FLANGE CONN TOOLS AND AUX. TOOLING
* DEPLOYMENT OF R.T. & A.F.T.
* DEPLOYMENT OF TOOLING DEPLOYMENT BASKET
(2)
R.O.V.
WORK SKID
R.T.
PIPELINE
SPOOLPIECE
* INSTALLATION OF R.T. ONTO PIPELINE
(3)
A.F.T.
PIPELINE
SPOOLPIECE
* INSTALLATION OF A.F.T. ONTO SPOOLPIECE
(4)
PULL-IN ANCHOR
R.T.
A.F.T.
* DEPLOYMENT OF A.F.T. ANCHORING SYSTEM TO R.T. USING R.O.V. AND REMOVAL OF FLANGE SEAL COVER

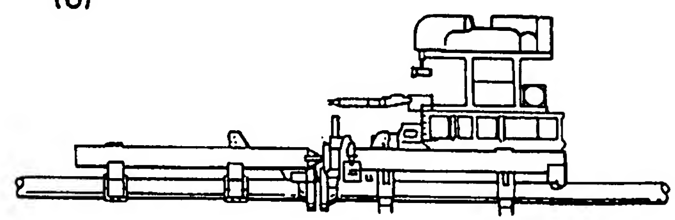
Fig. 17

(5)



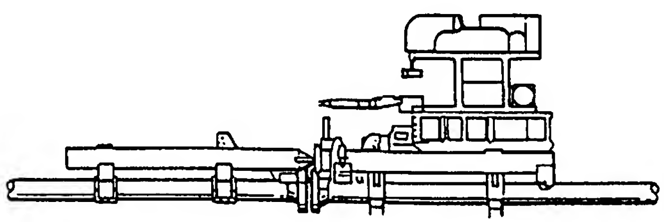
* STAB ANCHORS ENGAGED INTO R.T. READY FOR PULL-IN

(6)



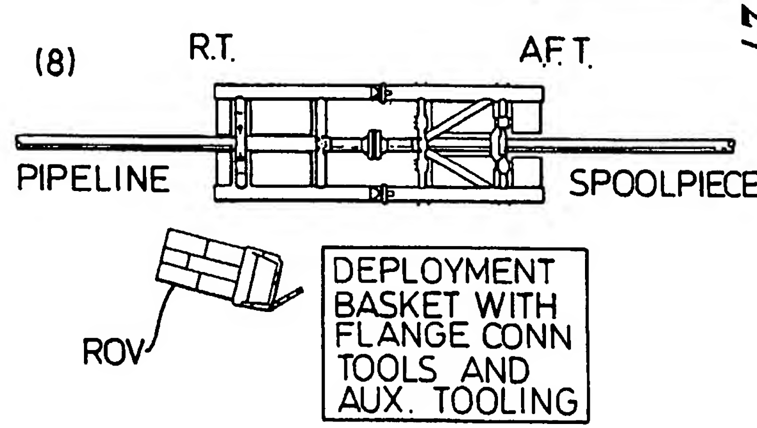
* PULL-IN COMPLETE AND FRAMES LOCKED TOGETHER

(7)



* PIPELINE AND SPOOLPIECE ALIGNMENT COMPLETE WITH THE USE OF THE R.T. & A.F.T. FRAMES

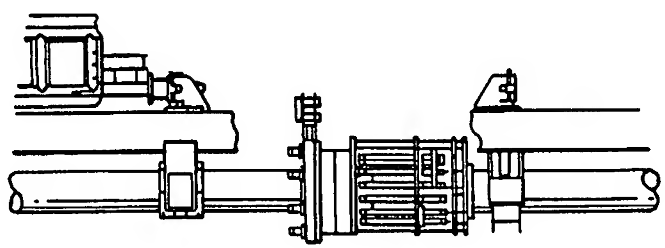
(8)



* R.O.V. COLLECTS NUT MAGAZINE FROM BASKET

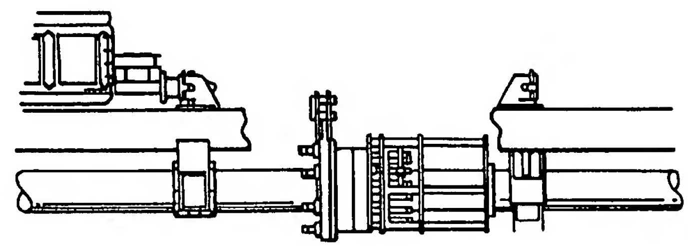
Fig. 18

(9)



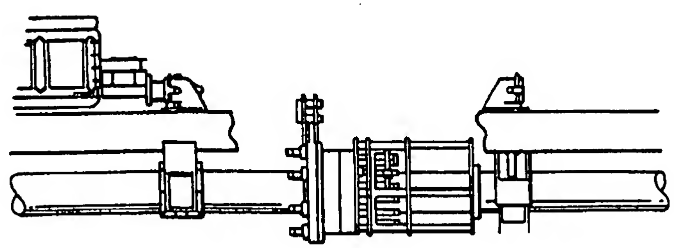
* R.O.V. INSTALLS NUT MAGAZINE

(10)



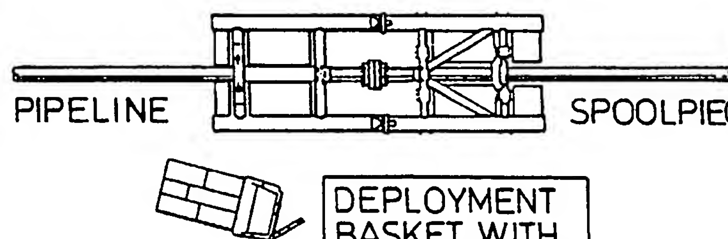
* BOLTS EXTENDED INTO NUT MAGAZINE AND ENGAGED AND NUT PAN DOWN

(11)



* BOLTS TENSIONED
* R.T. & A.F.T. FRAMES UNLOCKED

(12)



* FLANGE CONNECTION TOOLING REMOVED TO DEPLOYMENT BASKET

Fig. 19

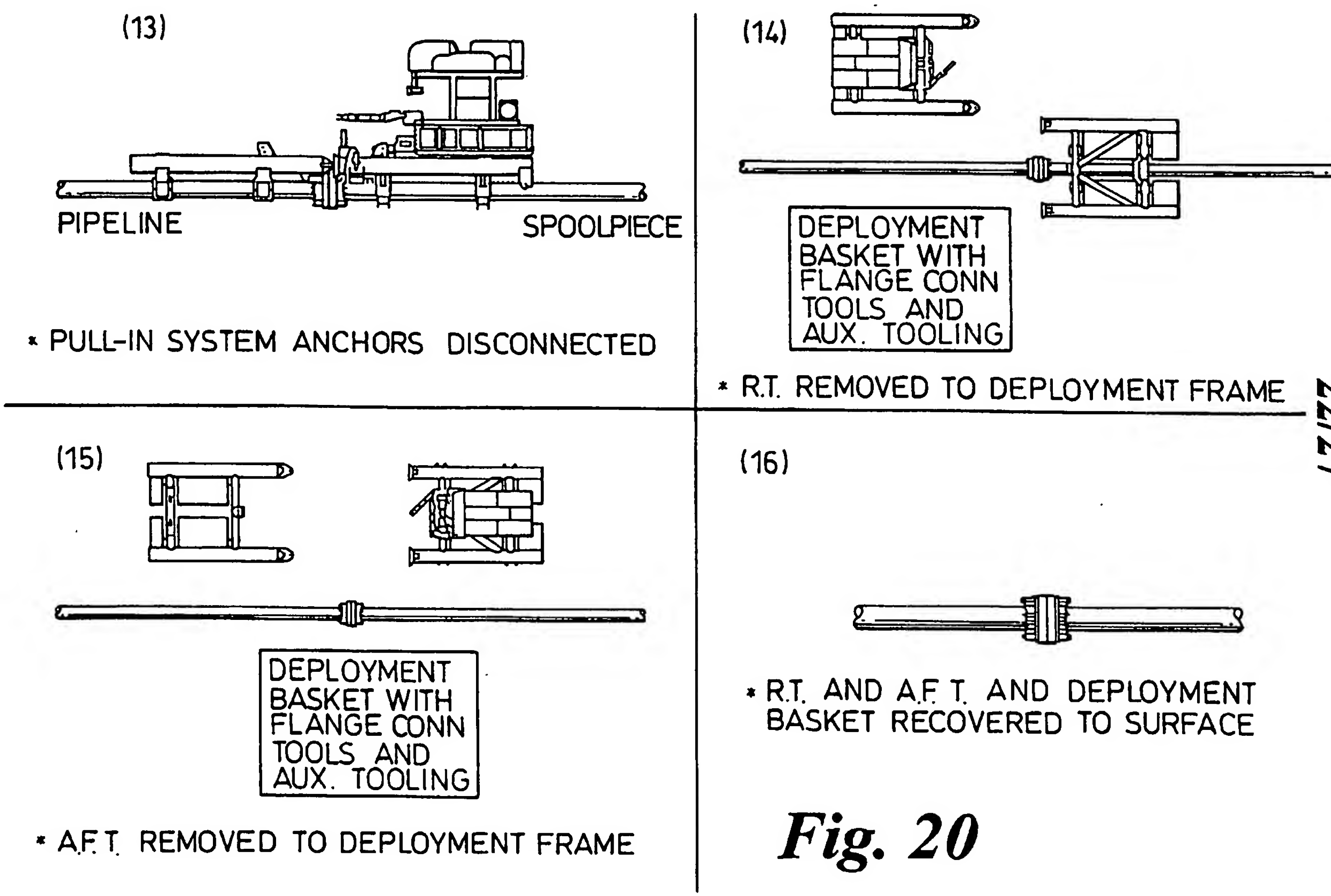

(13)
PIPELINE
SPOOLPIECE
* PULL-IN SYSTEM ANCHORS DISCONNECTED
(14)
DEPLOYMENT BASKET WITH FLANGE CONN TOOLS AND AUX. TOOLING
* R.T. REMOVED TO DEPLOYMENT FRAME
(15)
DEPLOYMENT BASKET WITH FLANGE CONN TOOLS AND AUX. TOOLING
* A.F.T. REMOVED TO DEPLOYMENT FRAME
(16)
* R.T. AND A.F.T. AND DEPLOYMENT BASKET RECOVERED TO SURFACE

Fig. 20

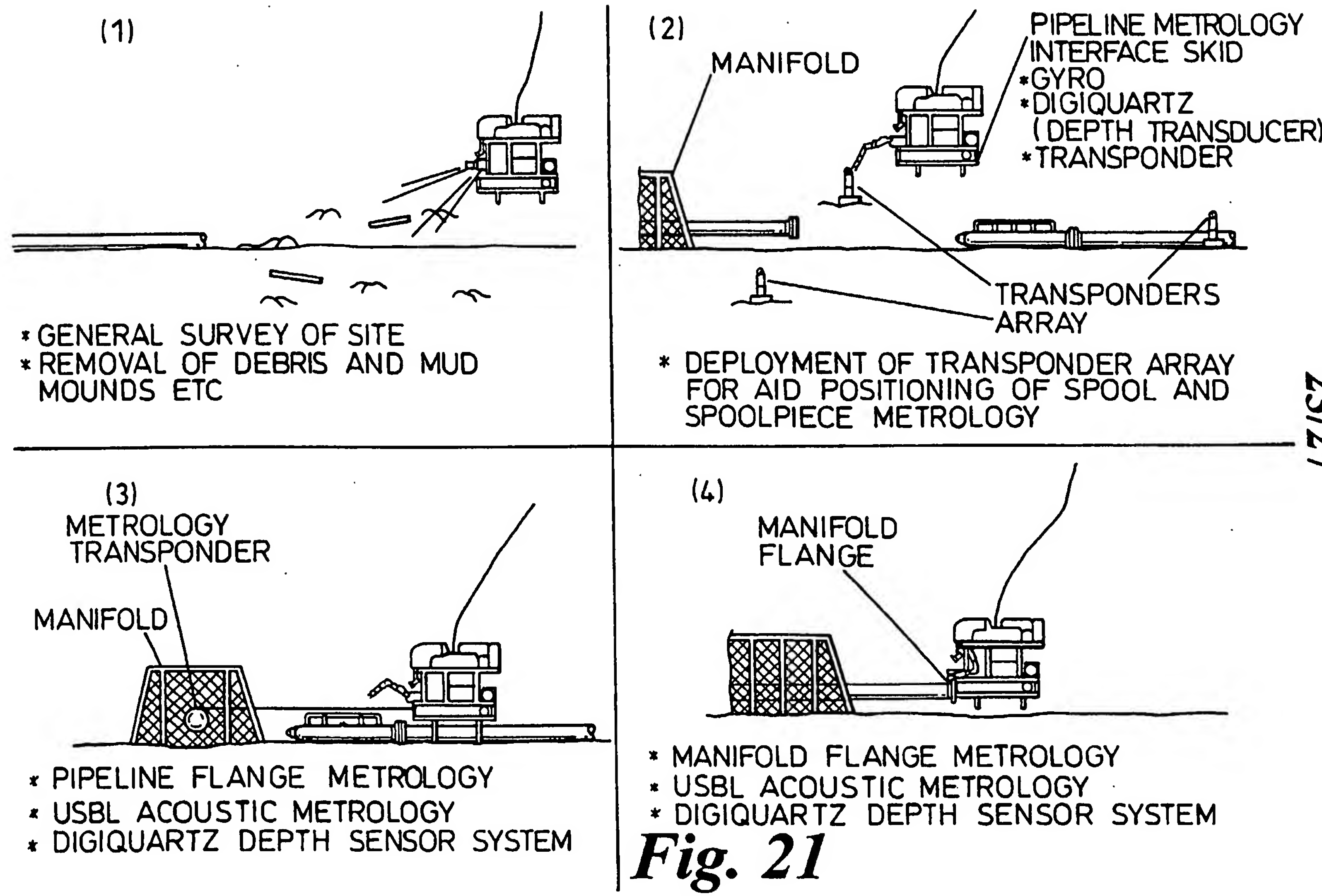

(1)
* GENERAL SURVEY OF SITE
* REMOVAL OF DEBRIS AND MUD MOUNDS ETC
(2)
MANIFOLD
PIPELINE METROLOGY INTERFACE SKID
*GYRO
*DIGIQUARTZ (DEPTH TRANSDUCER)
*TRANSPONDER
TRANSPONDERS ARRAY
* DEPLOYMENT OF TRANSPONDER ARRAY FOR AID POSITIONING OF SPOOL AND SPOOLPIECE METROLOGY
(3)
METROLOGY TRANSPONDER
MANIFOLD
* PIPELINE FLANGE METROLOGY
* USBL ACOUSTIC METROLOGY
* DIGIQUARTZ DEPTH SENSOR SYSTEM
(4)
MANIFOLD FLANGE
* MANIFOLD FLANGE METROLOGY
* USBL ACOUSTIC METROLOGY
* DIGIQUARTZ DEPTH SENSOR SYSTEM

Fig. 21

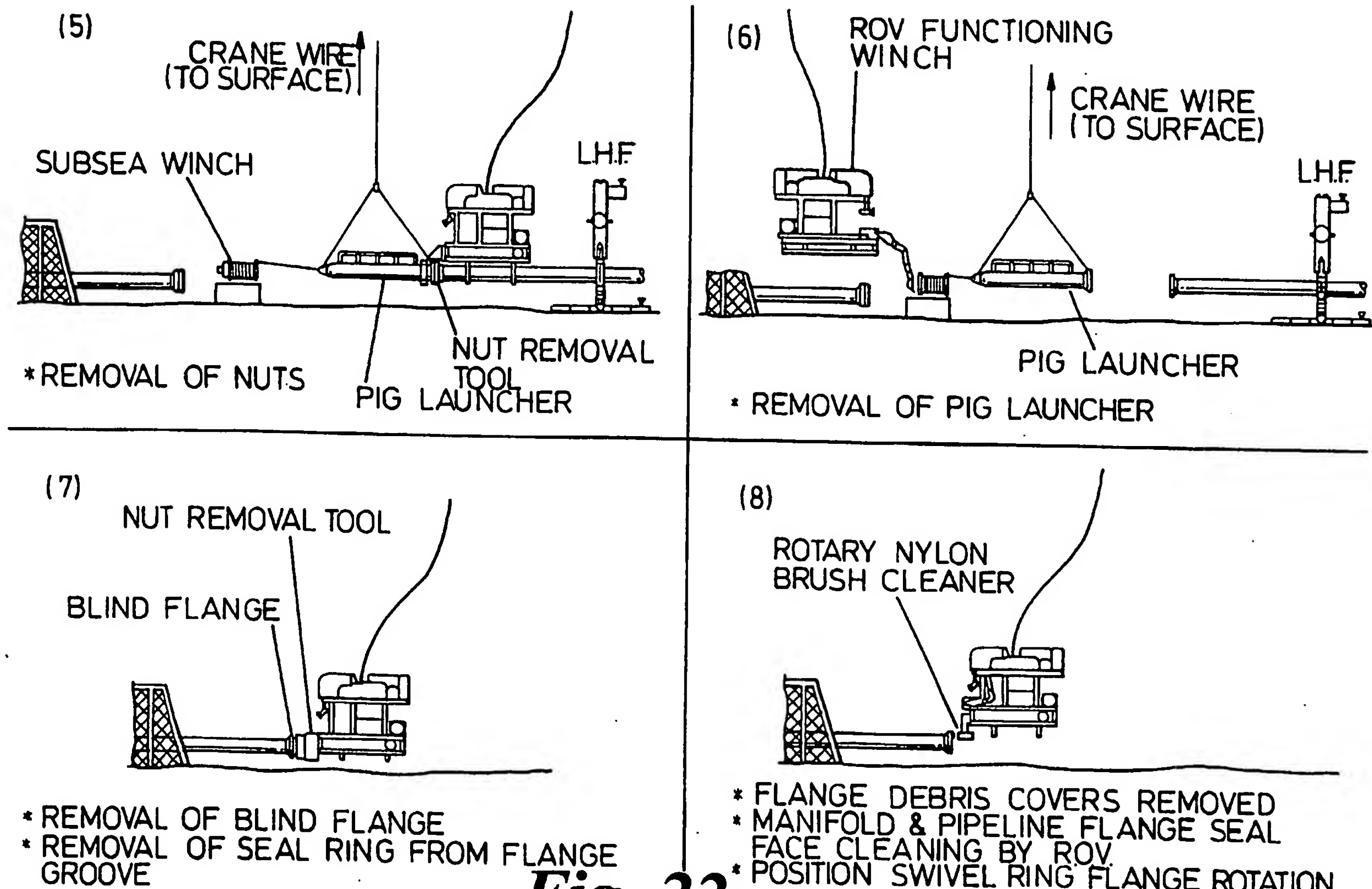

(5)
CRANE WIRE
(TO SURFACE)
SUBSEA WINCH
L.H.F
NUT REMOVAL TOOL
PIG LAUNCHER
* REMOVAL OF NUTS
(6)
ROV FUNCTIONING WINCH
CRANE WIRE
(TO SURFACE)
L.H.F
PIG LAUNCHER
* REMOVAL OF PIG LAUNCHER
(7)
NUT REMOVAL TOOL
BLIND FLANGE
* REMOVAL OF BLIND FLANGE
* REMOVAL OF SEAL RING FROM FLANGE GROOVE
(8)
ROTARY NYLON BRUSH CLEANER
* FLANGE DEBRIS COVERS REMOVED
* MANIFOLD & PIPELINE FLANGE SEAL FACE CLEANING BY ROV
* POSITION SWIVEL RING FLANGE ROTATION

Fig. 22

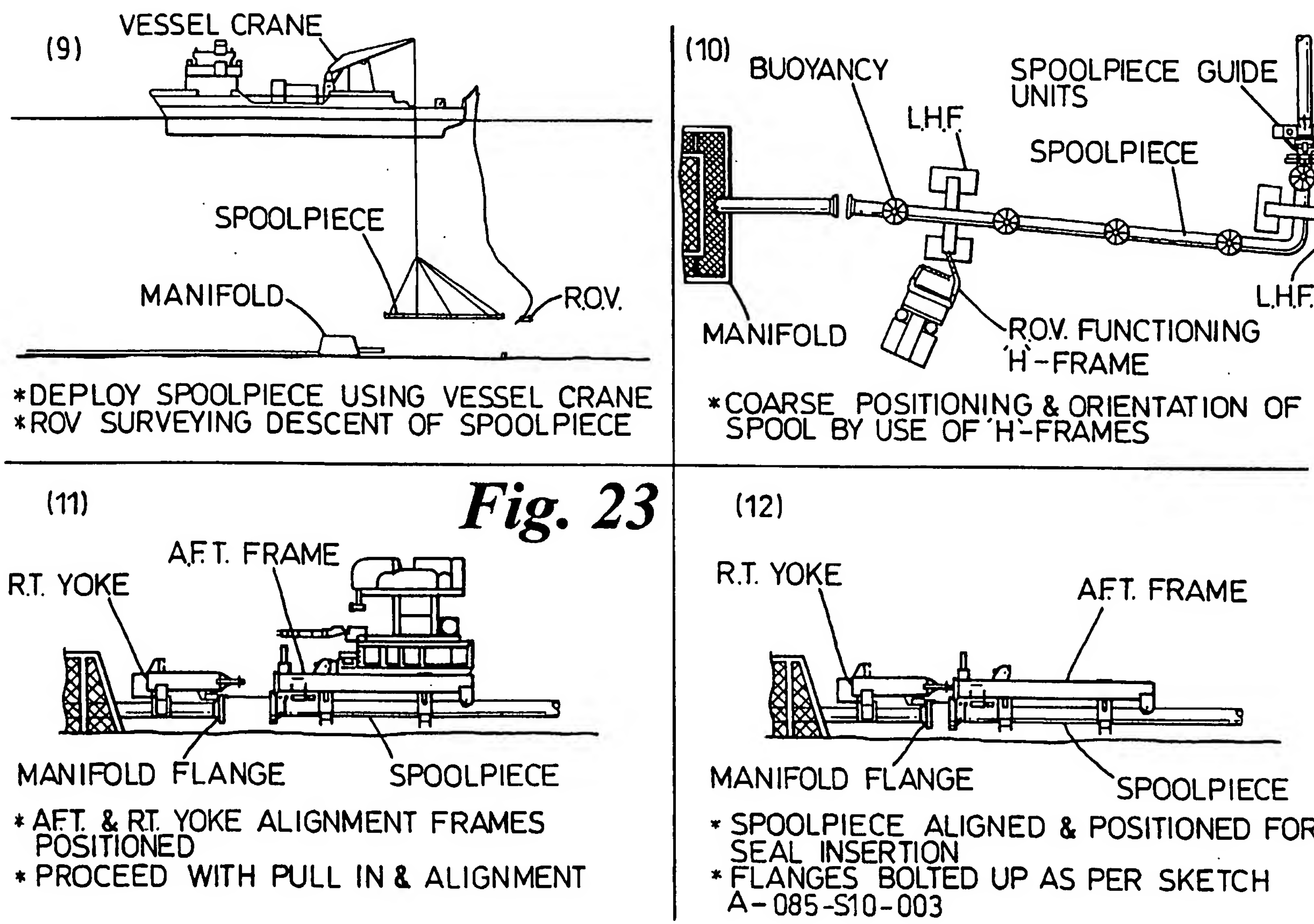

(9)
VESSEL CRANE
SPOOLPIECE
MANIFOLD
R.O.V.
*DEPLOY SPOOLPIECE USING VESSEL CRANE
*ROV SURVEYING DESCENT OF SPOOLPIECE
(10)
BUOYANCY
L.H.F.
SPOOLPIECE GUIDE UNITS
SPOOLPIECE
L.H.F.
MANIFOLD
R.O.V. FUNCTIONING 'H'-FRAME
*COARSE POSITIONING & ORIENTATION OF SPOOL BY USE OF 'H'-FRAMES
(11)
A.F.T. FRAME
R.T. YOKE
MANIFOLD FLANGE
SPOOLPIECE
* A.F.T. & R.T. YOKE ALIGNMENT FRAMES POSITIONED
* PROCEED WITH PULL IN & ALIGNMENT
(12)
R.T. YOKE
A.F.T. FRAME
MANIFOLD FLANGE
SPOOLPIECE
* SPOOLPIECE ALIGNED & POSITIONED FOR SEAL INSERTION
* FLANGES BOLTED UP AS PER SKETCH A-085-S10-003

Fig. 23

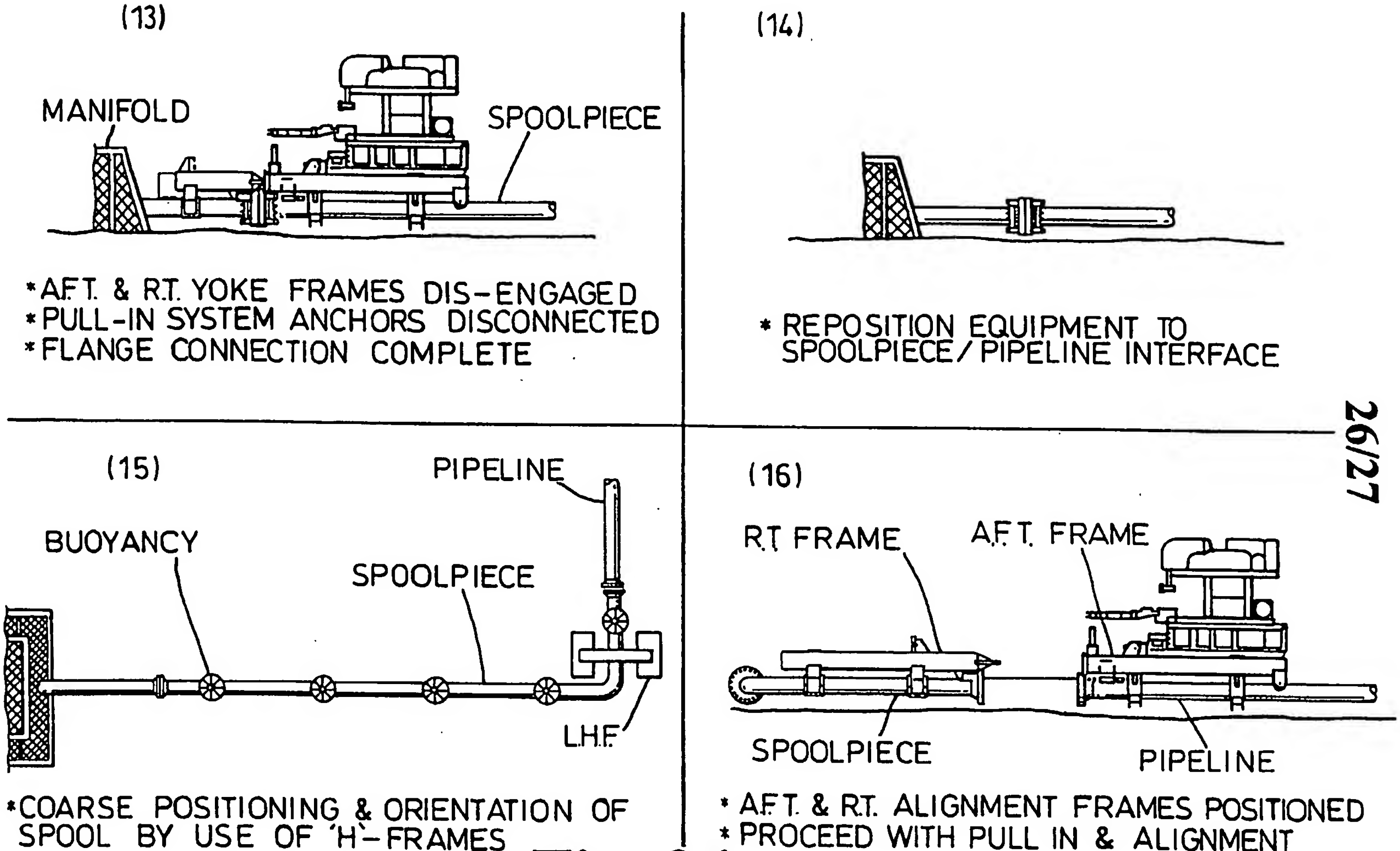
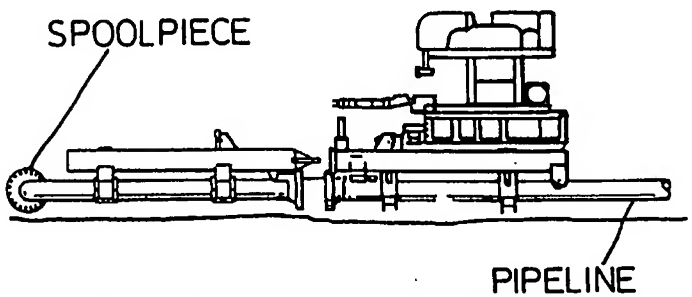

(13)
MANIFOLD
SPOOLPIECE
*AFT. & RT. YOKE FRAMES DIS-ENGAGED
*PULL-IN SYSTEM ANCHORS DISCONNECTED
*FLANGE CONNECTION COMPLETE
(14)
* REPOSITION EQUIPMENT TO SPOOLPIECE/PIPELINE INTERFACE
(15)
PIPELINE
BUOYANCY
SPOOLPIECE
LHF
*COARSE POSITIONING & ORIENTATION OF SPOOL BY USE OF 'H'-FRAMES
(16)
RT FRAME
AFT. FRAME
SPOOLPIECE
PIPELINE
* AFT. & RT. ALIGNMENT FRAMES POSITIONED
* PROCEED WITH PULL IN & ALIGNMENT

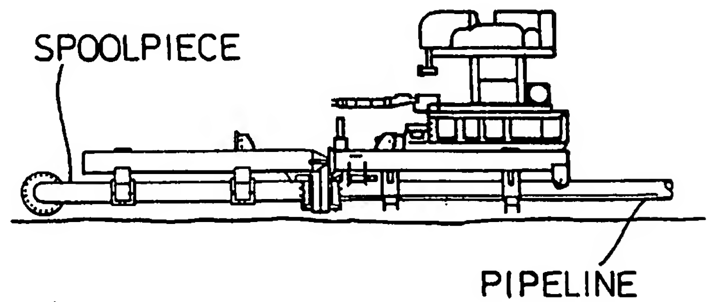
Fig. 24

(17)



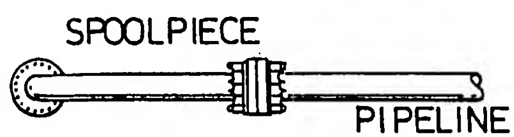
* SPOOLPIECE ALIGNED & POSITIONED FOR SEAL INSERTION
* FLANGES BOLTED AS PER SKETCH A–085-S10-003

(18)



* A.F.T. & R.T. FRAMES DIS-ENGAGED
* PULL-IN SYSTEM ANCHORS DISCONNECTED
* FLANGE CONNECTION COMPLETE

(19)



* R.T. AND A.F.T. AND DEPLOYMENT BASKET RECOVERED TO SURFACE

Fig. 25

"METHOD AND APPARATUS FOR CONNECTING UNDERWATER CONDUITS"

This invention relates to a method and apparatus for connecting underwater conduits and, more specifically, to a method and apparatus which is capable of performing the diverless connection of underwater flowlines - both flexible and rigid - in any combination of each other, and connection of the said flowlines to underwater structures such as flowline bases, Xmas trees, templates or similar.

There are various recognised methods for diverless connection of underwater flowlines to underwater structures. The methods used for such connections are characterised mainly by two principal factors: the use of permanently installed underwater hardware known as tie-in porch or reaction structures and the strict dependency upon the related connection system (connector).

Both the permanently installed underwater hardware and connection system are critical parameters. The items of hardware required to support the connection operations are usually installed during flowline or underwater structure installation: any deviation from standard procedures required by the installers could result in a very high cost impact making the system less competitive than other alternative options. Furthermore, the strict dependence upon a given connection system can limit the use of the system to certain applications.

The above reasons highlight the need for an alternative method which is able to overcome both the needs of permanently installed underwater hardware and the dependence upon a given connection system whilst ensuring the same operating reliability as existing systems. In addition, the selection

of an intervention philosophy requiring the use of neutrally buoyant tools optimises the flexibility of the presented method thus avoiding any dependency on the surface support vessel.

The aim of the present invention is to negate these drawbacks by providing a system which allows fully remote connection of underwater flowlines without using any permanently installed underwater hardware, allowing the use of any type of connection system, and performing all the operations using only the remotely operated vehicle to install and operate all the system's tools.

According to one aspect of the present invention there is provided a method of connecting underwater conduits from a support vessel on the surface comprising the steps of launching a remotely operated vehicle from the support vessel; launching connection apparatus from the support vessel; manipulating the remotely operated vehicle to dock with the connecting apparatus; installing the connection apparatus to one of the conduits; activating a docking clamp means using the remotely operated vehicle to capture the end of the first conduit; activating the connection apparatus to draw the second conduit to the first; connecting the two conduits together to form a continuous flowline; providing a sealed connection; and recovering the remotely operated vehicle and connection apparatus to the support vessel.

Each of the above method steps are carried out without the need for underwater personnel. Each step is monitored and controlled from the support vessel thereby increasing the efficiency and safety of the connection process.

Additionally, the method preferably includes the step of supporting the conduit on a frame above the seabed.

Advantageously, the remotely operated vehicle carries out a survey of the work site and sends a report to the support vessel prior to connection of the conduits.

According to the further aspect of the present invention there is provided an apparatus for connecting underwater conduits being controlled from a support vessel on the surface, the apparatus comprising a remotely controlled vehicle launchable and recoverable from the support vessel; connection apparatus launchable and recoverable from the support vessel; means for docking the remotely operated vehicle to the connection apparatus; means for mounting the connection apparatus on one or both of the conduits; means provided for capturing the end of the other conduit and drawing the second conduit to the first to enable a connection of the conduits to form a continuous flowline; means to effect the connection and means for providing a sealed joint.

Advantageously, each of the connection apparatus is launched in a sledge from the support vessel.

Preferably, a support frame is also launched from the support vessel, the support frame being placed around one or both (depending on the field layout) of the conduits by the remotely operated vehicle to raise the conduit from the seabed.

Advantageously, the frame is a lightweight metallic frame substantially H-shape in configuration.

Preferably an interface skid, launchable and recoverable from the support vessel, is provided to which the remotely controlled vehicle docks in order to provide mechanical, hydraulic and electronic docking terminals for the connection apparatus on the remotely controlled vehicle.

Conveniently, an interface collar is provided on the free end of the flexible conduits to allow the connection apparatus to be mounted in position of flexible conduits.

Advantageously, buoyancy modules are provided in addition to the support frame. These modules act along with the support frame thereby raising the conduit from the seabed to enable connection of the adjacent conduit to be carried out.

Conveniently, the support frame and the connection apparatus are substantially buoyant in water to enable manoeuvrability by means of the remotely operated vehicle.

Advantageously, the manipulation means on the remotely operated vehicle is an articulated arm having a closeable grab arrangement at the free end thereof.

Embodiments of the present invention will now be described with reference to and as shown in the accompanying drawings in which:

Fig 1	is a side view of the "diverless flowline connection system" part of the connection apparatus, fixed to the underside of the remotely operated vehicle; one aspect of the present intervention;
Fig 2	is a side view of a "deployment frame" for launching and recovering the connection means from a support vessel on the surface;
Fig 3	is a side view of an "interface collar", connected to a flexible pipeline;
Fig 4	shows view of an "axial force tool" part of the connection apparatus;

Fig 5	shows views of a "reaction tool" part of the connection apparatus;
Fig 5a	shows views of a "reaction yoke" part of the connection apparatus;
Fig 6	shows views of the "flange connection tools" used to perform the connection between two conduits of bolted flange type;
Fig 7	shows views of an "interface skid" to provide the interface between the remotely operated vehicle and the connection apparatus;
Fig 8	shows views of an "H" frame for supporting a rigid conduit above the seabed.
Fig 9	shows views of ancillary tools used to support the connection operation;
Fig 10	shows views of ancillary tools used to support the connection operation;
Fig 11	shows views of a sub sea utility winch;
Figs 12 to 14	are schematic view of the various stages of the operation in connecting two conduits together, one of which is flexible;
Figs 15 and 16	are schematic views of the various stages of the operation in connecting a flexible conduit to a sub sea structure (Xmas tree) using the DFCS;
Figs 17 and 21	show schematic views of the successive steps in connecting a rigid conduit to another rigid conduit; and
Figs 22 to 25	are schematic views showing a more detailed operational sequence of the connection apparatus.

The apparatus for connecting the conduits together comprises a complete set of tools and equipment able to perform, but not limited to, connections of rigid conduits to flexible conduits and rigid conduits to rigid spool pieces.

The said tools include a diverless flexible conduit connection system 10 (hereinafter referred to as a DFCS), an axial force tool 20 (AFT), a reaction tool 30 (RT), a flange connection tool 40 (FCT), an interface skid 50 (SKID), and equipment used to support offshore operations including a lightweight H-frame 60 (LHF) each of which will be described in greater detail below.

The said DFCS 10 which is shown in detail in Fig 1 (for more information refer to: Australian Patent No. 658239, United States Patent No. 5,593,249, Norwegian Patent No. 96,1761 and United Kingdom Patent No. GB2300439) consists of a structural skid frame with winches 13, stab-in anchors 12 and conduit clamp arms. The DFCS is deployed on the seabed on a deployment frame 15 (Fig 2) which can be raised or lowered from a support vessel (not shown) moored above the conduits C to be joined.

The Axial Force Tool (AFT) 20, shown in detail in Fig 4 is primarily a steel structure designed to perform close proximity tie-ins. It is used in conjunction with the Reaction Tool (RT) 30 and other items of the connection equipment to perform pull-in operations and flange alignment. The AFT can also be used for flexible lines pull-in since using a flange puller system with the possibility to increase, on demand, the available length of pulling wire.

The AFT comprises of a steel structure 21 manufactured either from commercially available standard or high strength steel. The structure includes two main lateral members, and a

combination of smaller members to stiffen the structure. In one configuration all members are tubular, some of which can be flooded and others which can be kept free of water to give additional buoyancy when submerged to reduce in water weight.

Mounted onto the structure are two hydraulically operated clamping modules 22, front and rear. The clamping modules serve two functions; they allow the AFT to be installed onto the pipe securely by means of clamping cylinders; and they allow the pipe to be deflected relative to the AFT structure.

The front and rear clamp modules are to manufacture to suit a range of pipe sizes. The clamping system will comprise of two cylinders fitted to each of the front and rear clamping modules. Clamping is via parallel control of the front and rear clamping cylinders. The possible addition of pilot operated check valves and an accumulator will allow a constant clamping force to be maintained on the pipe. Any shock loading in the clamping system could also be damped by the accumulator.

The use of an accumulator could also allow the ROV to leave the AFT in install the docking anchors in the RT should a second ROV be unavailable. In an emergency, the accumulator will be fitted with either an ROV operable dump valve or a flexible hose which can be cut. This will dump the contents of the accumulator, release the pipe clamps and allow the AFT to be recovered.

Also mounted onto the main structure is a wire rope type flange pulling system 23. This comprises of two flange pullers fitted to the port and starboard sides at the front of the AFT frame. The flange pulling system is used to provide the pull-in capability of the connection system.

Alternatively, the wire report pulling system could be replaced by standard sub sea winches or hydraulic cylinders.

The pull-in system will employ existing commercially available flange pulling technology, but adapted to suit the specific needs of ROV operation. The AFT will be fitted with a wire rope type flange pull-in cylinder on the port and starboard sides of the frame structure. Each puller is essentially a linear winch which pulls in a length of rope on each stroke.

The main structure is also fitted with a frame engagement system 24 which permits the AFT to engage and lock the RT structure to the AFT structure, so forming a single structure used for the pipe deflection operation.

Contained within the AFT is an hydraulic system which provides the means for power to the pull-in system, module pipe clamps, frame locking and clamping module deflection. Hydraulic supply for the AFT will be provided by the Interface Skid 50 and underslung from the host ROV. The AFT will be fitted with two interconnected hydraulic systems; one medium pressure; and one high pressure. The medium pressure system will be used but not limited to control pipe clamps, clamping module vertical motion and frame locking functions. The high pressure system will be used but not limited to provide control of clamp carriage horizontal motion (pipe/spool-piece deflection) and control of the pull-in system (pipe/spool-piece pull in).

The AFT is to contain may "failsafe" features which allow recovery of equipment with minimal damage if a failure (hydraulic or mechanical) occur during operations. The loads being transmitted to the conduit are also to be monitored to ensure no damage occurs.

The Reaction Tool (RT) 30 and Reaction Tool Yoke (RTY) 31, shown in figures 5 and 5a, are primarily steel structure designed to assist tie-in operations by reacting all forces applied by the axial force tool (AFT) 20. They are used in conjunction with the AFT and other items of the equipment spread to perform pull-in operations and flange alignment.

The RTY is used instead of the RT on conduits where accessible room to allow connection is tight (i.e. 1st end tie-in to a sub sea structure). This is since, as an additional requirement, the possibility of having a limited space behind the connection point was considered (this applies for example, in case of a riser with a gooseneck termination, a manifold flange etc). In these instances the alignment loads are reduced.

The RT comprises of a steel structure 32 manufactured from either commercially available standard or high strength steel. The same philosophy as for the AFT has been adopted.

Mounted onto the structure are two hydraulically operated clamping modules 33, front and rear.

The clamping modules allow the RT to be installed onto the pipeline securely by means of clamping cylinders. The clamping cylinders are included in a structural frame designed to pass all loads (axial force, lateral component and torsion) due to deflection of the pipe into the pipeline. This is achieved by the use of high force clamping cylinders which "grip" the tool to the pipeline - the structural frame being then used to avoid any other loads than push/pull acting on the cylinder rod.

As for the AFT, also the RT is provided with different clamps whose size depend upon certain pipe sizes.

Also mounted onto the front of the main structure are the receptacles 34 for anchoring the flange pulling wire ropes of the AFT pull-in system.

The main structure is also fitted with a frame engagement system 35 which permits the RT to engage with the AFT structure, so forming a single structure used for the pipe deflection operation.

Contained within the RT is a hydraulic system which provides the means for power to the clamping module pipe clamps. The RT will be fitted with a dual port female stab to provide control of hydraulic services. Hydraulic supply for the RT will be provided by the interface skid and underslung from the host ROV. The RT will be fitted with two interconnected hydraulic systems; one medium pressure; and one high pressure. The medium pressure system will be used but not limited to move the pipe clamps onto the pipeline and the high pressure system is used but not limited to the high clamping force necessary.

The RT yoke is essentially a reduced length RT with only one clamping module fitted. Clamping module size is as for RT.

The Flange Connection Tooling System (FCT) 40, shown in detail in Fig 6, comprises a suite of tools whose purpose it is to effect a bolted flange connection. The tools are deployed either pre-installed on the pipe, sub sea deployed by manipulator, or flown into position by the ROV, depending on the size of the pipeline.

Part of the FCT system is a Nut Magazine 41 which is constructed in two hinged half housing containing the full

quota of nuts required to connect the flanges. The two half housings are connected by an over-centre clamp mechanism.

The magazine is placed over the pipeline (at the Reaction Tool side) by the ROV using either a manipulator "T" bar (for pipelines 4" to 10") or a docking point 42 (for pipelines 12" upwards). The clamp mechanism can then be operated to lock the magazine around the pipeline.

The Reaction Tool or yoke (space permitting) is employed to retain the magazine axially and force it up to the rear of the pipeline fixed flange.

Each nut is held within a machined toothed sprocket. The sprockets are driven round by the operation of hydraulic motors, thus rotating the nuts to engage with the studs when they are introduced.

Hydraulic fluid is supplied to the motors by an ROV dual port hot stab 43. The hot stab receptacle is mounted on bracketry near the docking point.

Rotary alignment of the magazine, to align each nut with it's respective bolt hole, is achieved by the intrusion of two guide pins from the Bolt Insertion/Tensioning Tool (BITT) 45 into holes machined into the nut magazine body. A tapered lead-in cone is added to ease the intrusion of the pins.

Solid buoyancy blocks are attached to sides of the magazine to reduce the in water weight of the tool and enable ROV handling.

Another part of the FCT system is the Bolt Insertion/Tensioning Tool (BITT) 45 which contains a magazine 46 of retained bolts, which are to be inserted through the pipe flanges. The magazine also contains a quantity of stud

tensioner units into which the bolts are loaded before deployment.

The magazine is fixed within a surrounding deployment structure which provides clamp, rotation and extend hydraulic actuations.

The structure 47 is constructed of a series of horseshoe shaped plates which locate over the spool-piece outside diameter. The plates are connected by slide tubes (which run from the rear plate to the front plate) and two linear, hydraulic cylinders.

The magazine is contained within two central horseshoe plates. These two plates are fixed together by bearing housings which guide the unit along the slide tubes.

The magazine is constructed in two hinged half housings containing (if space permits) 100% coverage of stud tensioners. The two halves are pivoted to open and close around the pipe by two hydraulic clamp cylinders 48.

The rear horseshoe plate locates against the AFT 20 which provides an axial reaction to the forward movement of the bolt magazine. The AFT also provides a key which the horseshoe plate locates with to provide a reaction to rotational movement, therefore mounted at the rear of the BITT is a hydraulic cylinder which rotates the tool around the pipe to align the bolts with the bolt holes of the swivel flange. This cylinder is also capable of rotating the tool together with the swivel flange to align the bolts to the fixed flange bolt holes.

The tensioner units are made up of three parts, the load-bridge, the tensioner jack and the reaction nut.

For this application (ROV operated) the fwd mounted load-bridge incorporates a motor ear drive to rotate the nut down the stud during tensioning. Each nut is held within a machined toothed sprocket. Each sprocket is driven round by the operation of a hydraulic motor, thus rotating the nuts.

The tensioner jack is a conventional unit which has pressure intensified hydraulic fluid supplied to an annulus of the correct area to provide the sufficient tension to the bolt.

At the rear of the tensioner is the reaction nut. The reaction nut is a split collet which has a thread profile machined on its inside diameter. The reaction nut can be opened and closed around the threaded stub by the actuation of a small linear hydraulic cylinder or the operation of a hydraulic motor. This grips the stud and provided the reaction to the tensioner jack.

If it is not possible to achieve 100% coverage of the flange bolts with the tensioner units then the magazine will be divided into two parts. A part which retains the 100% bolts and a part which contains the 50% tensioner units. The bolt magazine shall operate as previously described, however the tensioner magazine requires fwd/aft movement and a rotation movement. These actuations will be incorporated into the existing structure by the addition of slide tubes, bearing housings, and mounting plates similar to those described above but with smaller strokes.

The tool contains an integrated control system based around a hydraulic valve manifold 49. The manifold will have a built-in facility to accommodate cameras and lighting on the tool. Power to the manifold will be via a composite

electrical/hydraulic hot stab connector deployed from the tooling skid using a manipulator arm.

The tool is deployed/removed from the pipe by the ROV utilising a docking point.

Solid buoyancy blocks are attached to the structure of the tool to reduce the in water weight and enable ROV handling after the bolts have been released.

To allow the ROV to interface with the AFT, RT and FCT, and provide hydraulic and electrical power to them, a tooling Interface Skid 50, shown in detail in Fig 7 is necessary. The interface skid will also allow isolation of the AFT, RT and FCT hydraulic systems from the host ROV, thus preventing any contamination of the host ROV hydraulic system leading to operational complications and failure.

The skid will comprise of an aluminium structure 51 containing an isolated hydraulic system 52, mechanical interface points 53 and buoyancy.

The skid structure is designed to allow the ROV to interface with either the AFT, RT and FCT by means of mechanical docking probes 53.

Electrical and hydraulic connections will be made between the ROV and the AFT and the FCT via a sub sea stab connector 54 located on the interface skid. This will pass hydraulic power, electrical power and command signals from the ROV to the AFT tooling manifold.

The skid is also fitted with a dual port stab 55 to allow a switch-able hydraulic supply to be available for the RT and the lightweight H-frames.

Control of the mechanical docking probes and eletro-hydraulic stab connector is hydraulic from the ROV. Fail-safe systems installed on the skid will allow the ROV/skid to disengage from either tool after loss of hydraulic power.

Buoyancy will be contained within the skid structure to provide the skid with a neutral in-water weight.

The tooling skid is mechanically attached to the ROV and is used as an interface between the ROV and the tool. The skid independent hydraulic system is switched on by a pilot hydraulic signal from the ROV. This then makes hydraulic power available at the electro-hydraulic and dual port stabs on the skid.

Electrical power from the ROV is passed directly to the tool via the electro-hydraulic stab. Control of the tooling manifold on the AFT is then possible via electrical command signals from the ROV.

Hydraulic power on the tooling skid can be switched between automated electro-hydraulic stab, articulated arm deployed electro-hydraulic stab, articulated arm deployed hydraulic dual-port stabs or a combination.

The tooling skid is fitted with a mechanical interface point at the front to allow the ROV to lock on to and pick-up either the connection equipment tools. The skid may also be fitted with vertical attachment points to reduce the loading on the front interface point.

Additional equipment is required to support the connection system operations, these include a Lightweight H-frame (LHF) 60, a pipeline Metrology System, a Seal Insertion and Removal Tool (SIRT) 65 and 66, a Blind Flange Removal Tool (BFRT) 67, a Pig Launcher Removal Tool (PLRT), a Flange

Spreader Tool (FST), a Spoolpiece Installation Guide Tool (SIGT) 68, a Flange Cleaning Tool (FCT) 69, a Sub sea Winch 70, and finally a Dead Man Anchor, each of which will be described in greater detail below.

The Lightweight H-frame (LHF) 60, shown in detail in Fig 8, is an ROV deployed and operated tool, designed to lift and position rigid flowlines during tie-in operations. The system is of a low weight/low force which guarantees its installation and operation by a standard work class ROV.

The H-frame can operate at up to 2500m water depth, i.e, all operations are performed without any diver assistance. It can also be easily adapted as each field will have its own specific requirements.

H-frames are generally used in pairs.

The LHF is a aluminium structure composed of two foundations pads 61, two vertical legs 62, a connection frame 63 and a clamp 64.

The foundations pads 61 are designed to have stability in soft soil with low shear strength. However, in case a lower bearing capacity is found, by replacing the feet almost all soil types can be faced. The pads may also include two water injection hot-stabs to allow separation of the mud mats from the pads.

The two legs 62 can be extended in order to pick up a pipe buried 250mm in the seabed and hold it up to 750mm from the seabed and the clamp can be translated +/- 500mm with respect to the centre line of the structure.

The clamp 64 is a scissors type, hydraulically operated by a single acting cylinder. The jaws of the clamp are able

to grab and lift a partially buried ridge pipeline. Through additional spacers, the same set of jaws can cope with different pipe sizes.

Dual port hydraulic hot stabs are provided on the LHF to allow the ROV to control the clamping, horizontal and vertical translation functions.

As the primary option, the LHF will be designed to be fully ROV deployable. This will require a mechanical interface to allow the ROV to dock onto the LHF and sufficient buoyancy modules (syntactic foam) will be required to maintain the tool with a slightly negative in water weight.

The Metrology System can be one of two systems commercially available sub sea use with an ROV, there are either an Acoustic Metrology System or a Taut Wire Metrology System.

The Acoustic Metrology System consists of an ROV underslung skid/frame that has mechanical interfaces on the front end, a pipeline engagement profile at the bottom and the acoustic metrology survey systems mounted within it. The acoustic equipment is primarily: a survey for measurement of orientation, relative to magnetic north; a USBL transponder, for positional measurement relative to the transponder array; and a depth transducer for accurate relative depth measurement.

All survey/metrology signal data from the systems on the skid is sent to the surface via the ROV umbilical.

The Taut Wire metrology system is a purely mechanical system that relies on protractors at the attached end points, i.e the two flanges or suitable steelwork attached to the

blind flange and/or pig launcher, for visual measurement of relative angles.

The distance between the flanges is measured by a mechanical odometer system that measures wire as it is paid out when the ROV flies the connecting wire from one flange to the other.

The Seal Insertion Tool (SIT) 65, shown in detail in Fig 9 is deployed by the ROV manipulator in a carrier fitted with an ROV T-bar handle. The seal is suspended in a support structure and located onto the ends of the partially exposed bolt heads. Once the flange bolts are fully inserted the insertion tool may be removed.

The Seal Removal Tool (SRT) 66, also shown in detail in Fig 9, is a contingency tool in the event that the face seal does not come away with the blind flange and remains attached in the groove of the weld-neck flange.

The tool will have a cylindrical body with a conical lead-in profile and will be inserted by ROV manipulator into the weld-neck flange. A pair of locking shoes will be actuated by hydraulic cylinders to "friction grip" the inside of the seal ring. The seal assembly can then be jacked off the sealing face without damage to the face.

The Blind Flange Removal Tool (BFRT) 67, shown in detail in Fig 10, is an ROV operated tool, designed to cut the studs and nuts on a blind flange to enable removal. The BFRT is divided in three parts: the locking system; the stud cutting system; and the nut cutting system.

The locking system is a docking nose which is positioned in the flange interface and locks in with four dogs hydraulically operated. The surface in contact is knurled to

provide a better grip. The flange interface is a simple cylinder with an internal diameter to suit the BFRT nose, with a guiding cone entrance.

On the locking system is mounted a rotary actuator to allow 180 degree rotation of the cutting tools composed of two horizontal, hydraulic motor driven grinding discs mounted both sides of the rotary actuator, which cuts the studs above the nuts.

The pig launcher removal tool is a traditional ROV operated torque tool. Due to the reduced pressures during pigging operation, the pig launcher bolts will not be tensioned and can be removed using standard tooling.

The flange spreader tool is a contingency tool in the event that it is not possible to remove the pig launcher or blind flange once the flange fixing bolts/nuts have been removed.

The flange spreader tool will consist of a steel framework which is deployed over the flange joint. Within the frame is contained a pair of commercially available flange spreading tools which can be extended forward to engage in the flange joint. The tools are then operated in the convention manner by extending a chisel head into the joint to effect separation.

The Spoolpiece Installation Guide Tool (SIGT) 68, shown in detail in Fig 10 also acts as protection for the pre-installed flange face seal.

The SIGT consists of two mating parts: the male guide; and the female receptacle.

The male guide consists of an ROV deployable pipe clamp fitted with a conventional guide post. The clamp is deployed onto the pipeline prior to installation of the spoolpiece by the ROV and activated through a hydraulic hot stab. An accumulator maintains the clamp in position and the ROV can leave the area whilst the spoolpiece is deployed.

The female receptacle is installed on the spoolpiece mating flange diameter prior to deployment of the spoolpiece and also acts as a flange seal face protector. The guide is held in place by a clamp which is maintained by an accumulator. During spoolpiece deployment the ROV monitors and guides the female receptacle into position on the male guide post.

Once deployment of the spoolpiece is complete, the female guide receptacle is opened and removed by the ROV. The male guide can then also be removed by the ROV. Both items are removed to the tooling basket.

The Flange Cleaning Tool 69, shown in detail in Fig 9, is hydraulically operated rotating brush in conjunction with a LP Water Jet system. The brush is made up from soft scouring pads several layers thick, secured to a central spindle protected to prevent "metal to metal" contact on the flange face and seal area.

The brush may be required to be changed out due to wear on the prolonged cleaning sections.

The brush is mounted on to a small, high speed hydraulic motor with a T-bar suitable for manipulating operation. Incorporated into the T-bar is a bracket for mounting a camera and light unit to give "close-up" Pre Clean inspection,

continuous monitoring during Flange Face Cleaning and Post cleaning inspection.

A LP Water Jet is used to remove light debris and mud from the flange face and for final clean-up before the post cleaning inspection.

An option on the rotating brush unit is a HP water jet system to clean the Flange Face set to a level safe for the Flange material preventing any possibility of damage.

The Sub Sea Utility Winch 70, shown in detail in Fig 11 is an ROV operated hydraulic winch mounted on a swivel frame on a clump weight base. It will be used to aid the positioning of the rigid flowline and spool-piece from 4" OD up to 24" OD during tie in operations. The sub sea winch can operate at 2500m water depth, i.e all operations are performed without any diver assistance.

The sub sea winch consists of a base frame, winch support frame turntable (360°) and a hydraulic winch system.

The base frame is designed to keep the winch in position during pull in of the winch wire rope. The base frame consists of a steel frame with a concrete in-fill. It also has four lift points for easy deployment.

The winch support frame can rotate 360° horizontally to allow alignment. This includes cable storage bull horns that allows the winch wire rope to be free pulled out from the winch without hydraulic actuation. The support frame is constructed from steel.

The sub sea winch system consists of a hydraulic motor connected to the wire rope drum via a gearbox and hydraulic

brake. The winch has a line feed in/out measurement system in the form of a turns counter.

For docking with the ROV a docking cone and a dual port hot-stab receptacle are located on the top of the structure. The dual port hot-stab hydraulically actuates the winch in and out operations of the sub sea winch using the ROV.

The dead man anchor or bollard clump weight as it is sometimes called, is essentially a steel frame/concrete in-fill gravity anchor with a bollard centrally mounted. It is a passive structure and provides a reaction point for pulling operations sub sea, such as pulling the pig launcher away from the flowline or coarse alignment of the spool-piece.

Referring now to a first embodiment of the method of connecting underwater conduits together, shown in Fig's 12, 13 and 14, a flexible conduit C' fitted with a suitable DFCS interface collar 16 (as shown in detail in Fig 3) is laid down on the seabed 100 within a target area. A LHF 60 is deployed and clamped to the flexible conduit C' in accordance with known techniques. The LHF 60 is launched from a support vessel moored above the connection site. The interface collar 16 allows the DFCS 10 described above to be locked in the conduit C'.

The RT (shown in detail in figure 6) is located on its deployment frame. The DFCS 10 (shown in detail in fig 1) is located on its deployment frame 15 (refer to Fig 2) together with a torque tool, seal ring replacement tool and spare connector seal (not shown).

Depending on the size of the conduit C and on the height of the connector 75 from the seabed 100, buoyancy modules 85 may be installed on the second conduit C'. The said buoyancy

modules can be inflated from single air source, located on the seabed, and operated by the remotely operated vehicle.

A Remotely Operated Vehicle (ROV) 80 is launched to the work site from the support vessel and performs a survey of the said work site. Information retrieved from the survey is fed back to the support vessel so that the appropriate parameters for the connection can be determined. The remotely operated vehicle is provided with an articulated manipulation arm 81 which allows the remotely operated vehicle to pick up selected objects.

The ROV 80 docks onto the LHF 60 and places the frame in position around the free end of the first conduit C. The ROV then operates the clamp 64 of the frame which grabs and holds the rigid conduit C in position.

The ROV is disconnected from the LHF 60 and positioned to retrieve the RT 30 from its deployment frame and carry the RT 30 to a position above the conduit C. The RT 30 is then lowered onto the conduit C. The clamp arms 33 of the RT are activated in order to lock the RT in position on the conduit C.

The ROV is then operated to remove the protection cap from the said rigid conduit C.

The ROV then docks onto the DFCS 10 to make up its electro-hydraulic connector. The flowline clamp arms of the DFCS are then opened to enable the DFCS to be retrieved from the deployment frame.

The ROV is then positioned adjacent the RT 30 and moves forward to dock the anchors 12 of the DFCS into the receptacles 34 of the RT. This action anchors the ends of the two DFCS winches 13 (refer to Fig 1) to the RT 30.

In Fig 13 the ROV activates the DFCS winches 13 pay out winch ropes 14 and, at the same time moves back to a position above the interface collar 16 of the flexible conduit C'. The ROV then lowers the DFCS 10 onto the second conduit C', over the interface collar 75 and activates the flowline clamp arms. This pulls the flexible conduit out of the sand/mud at the seabed and locks the DFCS 10 to it.

Mechanical indicators (not shown) provide a means to verify that the DFCS 10 is securely engaged over the axial load reaction shear keys to the interface collar 16.

The DFCS winches 13 are activated to commence pulling of the flexible conduit C' up to the rigid conduit C. The winch rope tensioners are monitored during this operation to allow for adjustment if necessary. If the conduit C' is not horizontally aligned on the seabed 100 when the two conduits are close together and the hub (not shown) arrives at the connector 75, a utility winch 70 may be used to pull the conduit C' into position using a standard procedure.

The said sub sea utility winch 70 is deployed on the seabed from the surface support vessel, whereby the ROV can connect the wire rope from the said winch directly or via a Dead Man Anchor to the said flexible conduit. Once connected it can perform the following two functions; pull the conduit towards the utility winch; then lock in place the position of the conduit after pulling.

The winch system on the utility winch is actuated by a dual port hot-stab from the ROV that powers the hydraulic motor on the winch. If necessary the direction of the force being applied can deflected using the said Dead Man Anchor until the alignment of the free ends of the conduits has been

corrected. The method of locking the wire rope in position is by the use of a braking system on the winch wire drum.

If required, the final vertical alignment of the conduit C′ may be achieved by adjusting the buoyancy modules 85 positional along its length.

The DFCS 10 continues to pull the said flexible conduit C′ up to the said rigid conduit termination until the two are a defined distance apart. In Fig 14 the conduit hub (not shown) is drawn into the connector 75.

The flexible conduit protection cap is removed from the end of the said flexible conduit C′ by the ROV manipulator arm 81.

The said DFCS winches 13 continue to operate until the said flexible conduit hub is at a certain distance from the said rigid conduit hub. The final part of the pull-in is then performed using the said DFCS winches with the said DFCS slide tubes arresting the motion. This provides a controlled method of aligning the two as the final distance is made up. Visual confirmation is made with the ROV cameras.

The said ROV makes up the connection, the connector being a clamp connector, a collett connector, a bolted flange connector or any other suitable connection device.

An air hot stab is taken form the above mentioned seal ring test system (located on the ROV) and is inserted into a receptacle on the mated assembly. The said air hot stab is pressurised and the pressure monitored. This provides an external seal test verify the integrity of the seal between the two conduits.

If the pressure test fails, the joint is opened and the said flexible conduit retracted by hydraulically extending the said DFCS slide tubes. The ROV retrieves the seal ring replacement tool from the said DFCS deployment frame and uses it to remove the seal and replace it with a new one. The said flexible conduit is again pulled up and the procedure repeated until the seal test result is satisfactory.

Once a successful seal test has been completed the said DFCS disconnects the stab-in anchors from the said RT receptacles and unclasps and the said DFCS 10 from the said flexible conduit C'. The DFCS and said tools are returned to the respective deployment frames which are then ready for recovery to the surface.

The ROV docks onto the said RT 30 and removes it from the rigid conduit C and returns it to its deployment frame which is then ready for recovery to the surface.

The ROV releases the completed conduit assembly by releasing the clamp means 64 of the said LHF 60 which is then ready for recovery to the surface, additionally the ROV then deflates and recovers any buoyancy modules 85 which have been used.

Fig. 14 also shows the recovery to the surface of DFCS 10, RT 30 and the recover to the surface of the LHF.

Fig. Numbers 15 and 16 show the connection procedure to connect to flexible conduit to a subsea structure (Xmas tree) using the DFCS.

The method outlined above describes the connection of the rigid conduit C to a flexible conduit C'. However, in accordance with a second embodiment of the invention, a rigid conduit C may be connected to another rigid conduit C" and the

respective steps of this alternative method are described below. Similar components from the first method are described below. Similar components from the first method have been given the same reference numerals for ease of understanding.

Referring now to a second embodiment of the method of connecting underwater conduits together, in Fig. Numbers 17 to 21 a rigid conduit C is connected to rigid conduit C′ by the inclusion of a rigid spoolpiece C+.

The two rigid conduits C and C″ are laid on the seabed in accordance with known techniques (one of the conduits could be part of an underwater structure such as a flowline bases a Xmas trees a template or similar).

As shown in Fig. 17 the ROV 80 is launched to the worksite from the surface support vessel and performs a site survey sending information back to the support vessel for analysis. The ROV will locate and remove any significant debris, and dredge any problem areas around the pipeline flanges for access.

The chosen metrology equipment is launched to the seabed within a deployment basket or onboard the ROV. The ROV will then operate said metrology equipment to relay pipeline flange position information back to the support vessel for analysis. From this information a rigid spoolpiece C+ is fabricated onboard the support vessel to fit between the rigid conduit C and C″.

Operations support equipment is launched to the seabed from the support vessel. Type of support equipment required will depend upon field layout and hardware employed by field constructors. As a minimum two LHF's 60, a subsea utility winch 70 and a dead man anchor are required.

The LHF's are deployed on the seabed by the vessel crane, whereby the clamp is then located straddling the pipeline using the ROV. Once in position the LHF can perform the following two functions; clamp onto the rigid flowline with the lifting clamp 64; apply a horizontal and vertical movement to allow rough positioning of the rigid flowline.

The LHF clamp 64 is actuated by a hydraulic cylinder (activated by a hotstab from the ROV) that applies a 5 Tonne force to clamp securely onto the rigid flowline. The horizontal positioning of the rigid flow-line is achieved by the use of two horizontally mount hydraulic cylinders. These, in turn, move a sliding collar which is attached to the lifting clamp. The vertical positioning of the rigid flow-line is achieved by the use of two vertically mounted hydraulic cylinders 62. These are attached to feet 61 which react against the seabed.

Further preparation work may take place at this stage, as shown in Fig. 18, i.e. removal of the 1st end rigid conduit C flange protection cap or blind flange using the Blind Flange Removal Tool (BFRT) 67, removal of old seal using the Seal Removal Tool (SRT) 66, seal face cleaning using the Flange Cleaning tool (FCT) 69, installation of the Spoolpiece Installation Guide Tool (SIGT) 68, and removal of a Pig Launcher (if fitted) from the end of conduit C+.

The said rigid spoolpiece C+ is laid on the seabed within a specified target area within the pull-in capabilities of the connection apparatus, as shown in Fig. 19. If the said SIFT 68 is employed, then the ROV will be used to guide the spoolpiece so that the female receptacle of the SIGT on the spoolpiece C+ locates with the guidepost on the rigid conduit C.

The ROV is recovered to the surface support vessel to fit the Interface Skid 50 to the underside of the ROV structure and connect it's hydraulic and electrical system with that of the SKID 50. Once complete the ROV is once again launched to the seabed.

The Reaction Tool (RT) 30 or the Reaction Tool Yoke (RTY) 31 (dependent on the field layout), the Axial Force Tool (AFT) 20 and the Flange Connection Tool (FCT) 40 (dependent on the flange connector type) are deployed to the seabed from the surface support vessel. All units are contained with their respective deployment structures.

The RT 30 or RTY 31 are passive structures design to interface with the AFT and transmit the spool alignment forces from the AFT into the pipeline. To enable the RT or RTY to provide this reaction path, it is deployed by the ROV onto rigid conduit C, and is clamped using a friction clamp 33 onto the pipeline.

This is achieved as the ROV moves to the RT 30 and docks on to it mechanical interface, and makes up its hydraulic hot stab connector to provide the friction clamp 33 with hydraulic power. The RT clamps are opened to remove it from its deployment frame, from where it is flown by the ROV into position on the rigid conduit C. Once the RT has been deployed in the correct location, it is clamped onto the pipeline, no further operations are carried out form the RT. The RT is left installed on the pipeline with an accumulator and check valve system to maintain a constant clamping pressure as further operations are performed.

The following procedural steps are shown in Fig. Numbers 19, 20 and 21, and the connection apparatus operation is shown in more detail in Fig. Numbers 22 to 25.

After installation of the RT, the ROV moves to the AFT 20 and docks on to it's mechanical interface, and makes up it's electro-hydraulic connector 54 to provide the friction clamp 22 with hydraulic power. The AFT clamps are opened to remove it from it's deployment frame, from where it is flown by the ROV into position on the rigid spoolpiece C+. Once the AFT has been deployed in the correct location, it is clamped onto the pipeline using two hydraulically opened pipe clamps, front and rear. The AFT is left installed on the pipeline with an accumulator and check valve system to maintain a constant clamping pressure as further operations are performed.

The ROV then disengages from the AFT and using it's articulated arm 81 removes the SIGT 68 from the flanges of both the rigid spoolpiece C+ and the rigid conduit C, and helps recover them to the surface support vessel.

Again using it's articulated arm 81, the ROV removes the flange pull-in wire anchors 23 from the AFT and secures them into the corresponding RT anchor receptacles 34, as shown in Fig. 22.

The ROV once more docks into the mechanical interface of the AFT and makes up it's electro-hydraulic connector to provide the flange pull-in system with hydraulic power. Pull-in or the rigid spoolpiece C+ towards the rigid conduit C is achieved by the hydraulic operation of the flange pull-in system installed on the AFT. Port side and starboard side flange pull-in wires can be individually controlled.

As the AFT is pulled towards the RT, the clamping modules 22 of the AFT are free to float within the AFT structure. This allows the AFT and RT frames to attain alignment given that both the RT and AFT are clamped onto the rigid pipeline C and the rigid spool-piece C+ respectively.

As the AFT and RT are drawn towards each other, guides 35 at the front of the structures engage and ensure that the AFT and RT structure align with each other.

When the AFT and RT structure are fully docked, hydraulic locking pins 24 located on the AFT are engaged, so connecting the AFT and RT as one structure.

During pull-in the misalignment between the pipeline flange and spool-piece flange will remain, the clamping modules with the AFT will float in the horizontal and vertical planes to compensate for the misalignment.

Once locking of the AFT and RT structure has taken place and the AFT clamping carriages have been misplaced due to the flange misalignment, final alignment of the spool-piece will take place.

This is achieved by operation of the AFT clamping module horizontal and vertical deflection cylinders. Operation of these cylinders allows the spool-piece to be deflected back onto the centreline of the AFT structure and hence in alignment with the RT structure and consequently the mating flange.

The rigid conduit flanges are now ready for connection, as shown in Fig 23, the connector being a clamp connector, a collett connector, a bolted flange or any other type of suitable connection device.

The following describes a method for the connection of standard bolted flanges, and is shown in detail in Fig 24, where the flange on rigid conduit C is a fixed type, and the flange on rigid spoolpiece C+ is of a swivel type, using the previously described FCT 40.

The ROV disconnects from the AFT and docks into the mechanical interface of the BITT 45 and makes up it's electro-hydraulic connector to provide the BITT 45 with power. The BITT clamps are opened to remove it from it's deployment frame, from where it is flown by the ROV into position on the rigid spoolpiece C+. Once the BITT has been deployed in the correct location (in between the AFT structure and the spoolpiece C+ flange), it is clamped to the spool-piece with the bolts facing the swivel flange.

Connection of the flange is now ready to proceed as follows:

- By providing hydraulic power to the BITT the bolts are to be extended through the spoolpiece C+ flange bolt holes until protruding from the flange face.
- ROV to disconnect from the BITT and retrieve the Nut Magazine (NM) 41 from the deployment frame and clamp it in position around the rigid conduit C (in between the RT structure and the pipe flange).
- ROV to retrieve and deploy the seal carrier c/w seal and locate in the spoolpiece C+ flange face using the bolts as a guide.
- ROV to connect with the BITT once more to rotationally align the bolts c/w the spool-piece swivel flange with the pipe fixed flange holes, by hydraulically rotating the BITT structure 47.
- Alignment pins are to be hydraulically extended from the BITT and locate with receptacles in the NM to bring the NM and it's contained nuts into alignment with the flange holes.
- The bolts are then extended further through the aligned fixed flange and locate with the nuts contained with the NM.

- The NM hydraulic motors are operated by a hydraulic hot stab 43 from the ROV articulated arm, to engage and run the nuts down the bolts until the nuts are in contact with the rear of the flange face (i.e. all nuts are lightly tightened).
- The BITT then operates the tensioner jacks 46 to tension the bolts and run down the slackened nuts by operating the BITT motors until the motors stall. At this point the flanges will closed together and retain the seal.
- The tensioning operation is to be performed three times to each bolt.
- Once the flange connection has been completed the BITT disengages the reaction nuts and retracts the tensioner magazine leaving the installed bolts in place.
- The BITT is then recovered from the spoolpiece C+ by the ROV and deployed back into it's deployment/recovery frame. The NM is similarly removed from the rigid conduit C and deployed C and deployed back into said frame.

As described in the previous embodiment, an air hot stab is taken from the seal test system (located on the ROV) and is inserted into a receptacle on the mated flange assembly. The said air hot stab is pressurised and the pressure monitored. This provides an external seal test verify the integrity of the seal between the two conduits.

Once a successful seal test has been completed, the AFT deflection cylinder are retracted and the clamping modules are once again free to float. The pull-in system anchors are disengaged, and the AFT and RT structure are unlocked from each other. The pipe clamps can now be released on the AFT and the AFT can be recovered from the rigid spool-piece C+ and

placed back into it's deployment/recovery frame. Similarly the pipe clamps can now be released on the RT and the RT can be recovered from the rigid conduit C and placed back into it's deployment/recovery frame.

The sequence of events from start to finish is repeated to perform the connection at the second end of the spoolpiece, i.e connecting rigid spoolpiece C+ to rigid C'. To perform the second end connection the ROV will require to re-position the LHF's The surface support vessel will recover the FCT and re-load it with a full quota of nuts and bolts, then deploy it once more to the new location on the seabed.

Once a successful seal test has been completed at the 2nd end, then this completes the connection of the conduits to form a continuous flowline.

All items are then recovered to the surface, and the ROV performs a final site survey.

Each step of the above described methods including all possible combinations of them, can be performed without any need for immersed personnel.

The use of other types of connection system (clamp, collett or flange) is possible by using the relevant connection tool (torque tool for the clamp screw drives, hydraulic hot stab for the collet, and bolt tensioners or torque tools for the flange) forms of which are available on the market. The procedure to perform a seal test and to replace a seal will also be similar to that outlined above, but using different types of tools which are also readily available on the market.

CLAIMS

1. A method of connecting underwater conduits from a remote location comprising the steps of launching a remotely operated vehicle (ROV); launching connection apparatus; manipulating the ROV to install the connection apparatus at or on at least a first one of the conduits to be connected; using the ROV to capture the end of another conduit to be connected to the first one; activating the connection apparatus such that the respective first and other conduit ends to be connected are drawn together; connecting these conduit ends together to form a continuous flowline; providing a sealed connection and recovering the remotely operated vehicle and connection apparatus to the support vessel.

2. A method according to claim 1, wherein the ROV is manipulated to dock with the connection apparatus.

3. A method according to claim 1, or claim 2 wherein the connection apparatus is installed on a first one of the conduits to be connected, and a clamp means is activated by the ROV to capture an end of the other conduit to be connected to the first one, and that end is drawn to the first to enable connection.

4. A method according to any one claims 1 to 3 and further including the step of supporting at least one conduit on a frame above the seabed.

5. A method according to any one of claims 1 to 4, wherein the ROV carries out a survey of the work site and sends a report to the support vessel prior to connection of the conduits.

6. A method according to any one of claims 1 to 5, wherein the remote location is upon a support vessel.

7. A method according to claim 6, wherein the connection apparatus is launched in a sled from the support vessel.

8. A method according claim 6, wherein the ROV is launched from the support vessel.

9. An apparatus for connecting underwater conduits, same being controllable from a remote location, the apparatus comprising a remotely operated vehicle (ROV); connection apparatus; means for installing the connection apparatus at or on at least a first one of the conduits to be connected; means for capturing an end of a second one of said conduits to be connected, and means for drawing the respective ends to be connected together to enable a connection of the conduits to form a continuous flowline; means to effect the connection; and means for providing a sealed joint.

10. An apparatus according to claim 9 wherein the ROV has docking means for docking with the connection apparatus.

11. An apparatus according to claim 10 wherein said docking means comprises an interface skid, said skid providing docking terminals for docking between the connection apparatus and the remotely controlled vehicle.

12. An apparatus according to any one of claims 9 to 11 wherein the connection apparatus is installed on a first one of the conduits to be connected and said means for capturing is a clamp means activated by the ROV to enable an end of the second one of the conduits to be connected, to be drawn to the first one.

13. An apparatus according to any one of claims 9 to 12 comprising at least one support frame, the or each support frame being located with respect to one of the conduits by the remotely operated vehicle to raise the conduit from the sea bed.

14. An apparatus according to any one of claims 9 to 13, wherein an interface collar is located on the ends of the conduits to be connected whereby the connection apparatus can be installed.

15. An apparatus according to claim 13, wherein the support frame is a lightweight metallic frame of substantially H-shaped configuration.

16. An apparatus according to claim 13 or claim 15, wherein the support frame is a light weight metallic frame containing buoyancy modules to reduce its in-water weight.

17. An apparatus according to any one of claims 13 to 16, wherein the support frame and the connection apparatus are of substantially neutral buoyancy in water.

18. A method of remotely connecting underwater conduits from a support vessel substantially as hereinbefore described with reference to and as illustrated in Figs 12 to 16 of the accompanying drawings.

19. A method of connecting underwater conduits from a support vessel on the surface substantially as hereinbefore described with reference to and as illustrated in Figs 17 to 25 of the accompanying drawings.

20. An apparatus for connecting underwater conduits under control from a support vessel on the surface substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

The Patent Office

38.

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Claims searched: 1-20

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): F2P (PL2, PL9); F2G (G8)

Int Cl (Ed.6): F16L 1/26, 55/18

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
XP	GB 2316992 A	(ABB OFFSHORE), see especially Figs 1 to 1s.	1-3, 6, 8-10, 12, 14
X	GB 2300439 A	(SONSUB), see especially Figs 9 to 12.	1-3, 6-12
XP	WO 97/47856 A1	(COFLEXIP), see especially Figs 1, 2, 8 and 20.	1-4, 6, 8-14

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